Ventilation .. .. And Heating.

Principles · and · Application.

1888

B. F. Sturtevant, Boston, Mass., U. S. A.

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B. F. Sturtevant,

Boston, Mass.

B. F. STURTEVANT,
By Con. Eng'r.

VENTILATION

AND

HEATING.

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PRINCIPLES · AND · APPLICATION.

· 1888 ·

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Introductory.

MUCH has been written during the past century upon the subjects of ventilation and heating, the two often being treated separately as if having no connection with each other. Their happy combination in the System of Hot Air Heating and Ventilation, as attained by the use of the Sturtevant Patent Steam Hot Blast Apparatus, marks a great advance in this important matter.

We feel that, with an experience of twenty-five years and a record of over five thousand sales of this apparatus, we can honestly claim to be better equipped for and more familiar with the business than any other house in the country. A force of competent engineers has been trained in this particular line, so that we are fully prepared to furnish plans, submit estimates, take contracts and give instructions for the complete ventilation of buildings of all classes. The plant, as supplied by us, includes boilers, engines, fans, heaters, steam traps, piping, air ducts, and in fact everything pertaining to our department of the work. Contrary to the custom of consulting engineers, we make no charge for advice to our customers, but desire to have them fully informed in order that a proper application of our apparatus may be assured.

We need present here no written testimonials of the satisfactory results attained by our apparatus, but simply invite the careful attention of the reader to the descriptions here presented of the system as it is in active operation, and solicit correspondence with us and with the parties to whom reference is made.

B. F. Sturtevant,

Boston, Mass.

“No other method than that of impelling air by direct means, with a fan, is equally independent of accidental natural conditions, equally efficient for a desired result or equally controlable to suit the demands of those who are ventilated.”—Robert Briggs.

Ventilation.

Necessity of Ventilation. Of the necessity of ample and efficient ventilation, there can be no doubt in the mind of the general public. No one can sit for a number of hours in a crowded hall, provided with no other means of removing the vitiated air and replacing it by fresh, pure air, than that provided by doors and windows, without being seriously impressed with the necessity of a more complete and satisfactory system of ventilation. Only a careful consideration of the requirements of the human body will enable the designer to understandingly and successfully provide the means for healthful and pleasurable ventilation. The evil effects of lack of ventilation are made only too evident by such facts as that "death rates have been reduced by the introduction of efficient ventilating systems, in children's hospitals, from 50 to 5 per cent.; in surgical wards of general hospitals, from 44 to 13 per cent.; in army hospitals, from 23 to 6; in prisons, 80 to 8; among horses in army stables, from 19 to 1.5; and in stables during epidemic, the rate has been reduced 80 per cent."*

Air. Air being the prime supporter of life, health, and even life itself, are dependent upon the composition of the atmosphere. Although simply a mechanical mixture, yet certain gases of which it is composed, exist in almost unalterable proportions in the normal atmosphere. Oxygen and nitrogen, the principal constituents, are present in very nearly the proportion of one part of oxygen to four parts of nitrogen. Carbonic acid, the result of all combustion, either slow or rapid, exists in the very small proportion of three to four parts in ten thousand of air, while the aqueous vapor varies greatly with the temperature and exposure to water. In addition there is generally present in air in variable but exceedingly small quantities, ammonia, sulphureted hydrogen, sulphurous acid gas, floating organic and inorganic matter and local impurities.

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*Notes on Ventilation and Heating: Prof. S. H. Woodbridge, Mass. Inst. Tech., Boston, Mass.

Humidity. The condition of the air, relatively to the amount of vapor of water held in suspension in it, is expressed by the term humidity. By Actual Humidity is implied the actual weight of water vapor present in a given unit volume of air, while the term Relative Humidity expresses the relation between the actual vapor present in the air and that which it would contain if saturated. Obviously the air is saturated with moisture when it will hold no more. The actual humidity varies excessively with the temperature, so it will be seen that a statement of the relative humidity gives no indication of the exact amount of vapor present, unless the moisture carrying capacity of the air at the given temperature be known.

The accompanying Table No. 1 gives a clear idea of the relations existing between the weights of air and vapor, in saturated mixtures at different temperatures, and will be found exceedingly useful in calculations of heating and drying.

A portion of this table is more clearly represented graphically by the hygrometric chart, Fig. 1, the rapid increase in the capacity of the air for carrying off moisture, as the temperature of the air rises, being indicated by the curved lines, which represent 10, 20, etc., to 100 per cent. humidity; 100 per cent being the dew point. The horizontal line of figures, from 10 to 200, at the top of the chart, indicate the grains of moisture per cubic foot of air, while the temperature of the air is given in degrees Fahrenheit at the left of the chart.

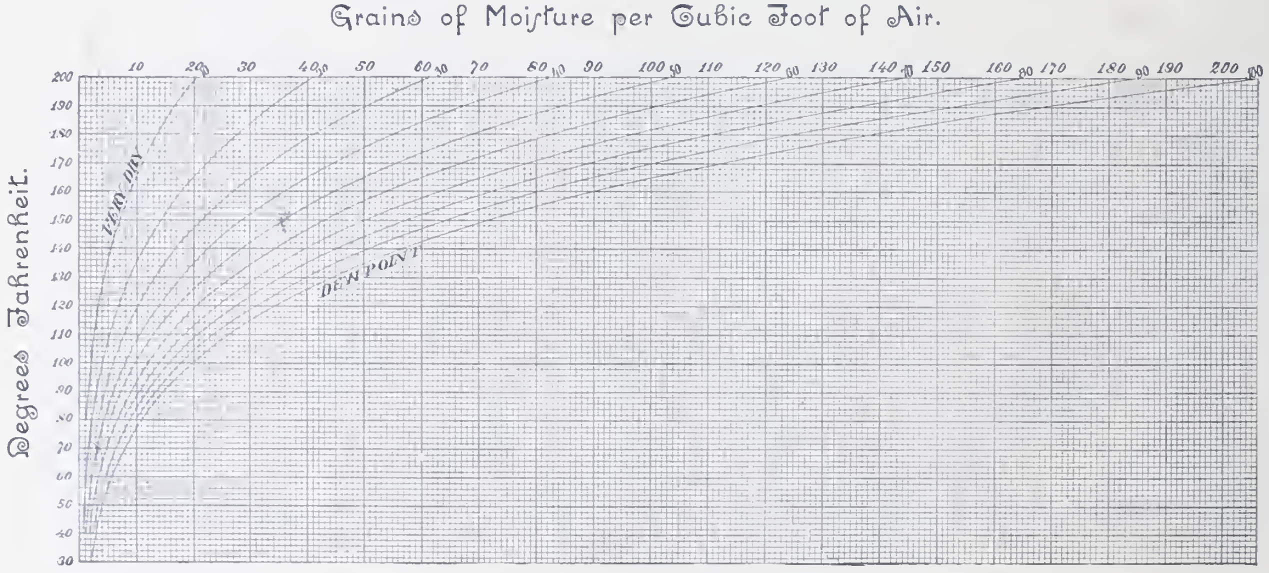

Fig. 1. Hygrometric Chart.

Carbonic Acid. Carbonic acid is not in itself a poisonous gas, and, contrary to general impressions, its presence in large quantities — as in soda water manufactories,— is neither disagreeable nor harmful. But as a product of respiration, par-

Table No. 1.

Of the weights of Air, Vapor of Water, and Saturated Mixtures of Air and Vapor at different Temperatures, under the ordinary Atmospheric Pressure of 29.921 inches of Mercury.

Temp. Fahr.	Volume of Dry Air at different temperatures, the volume at 32° being 1,000.	Weight of a Cubic Foot of Dry Air at different temperatures, in pounds.	Elastic Face of Vapor in inches of Mercury. Regnault.	Mixtures of Air Saturated with Vapor.						Cubic Feet of Vapor from 1 pound of Water at its own pressure in column 4
				Elastic Force of the Air in the Mixture of Air and Vapor in inches of Mercury.	Weight of a Cubic Foot of the Mixture of Air and Vapor.			Weight of Vapor mixed with 1 pound of Air in pounds.	Weight of Dry Air mixed with 1 pound of Vapor in pounds.	
					Weight of the Air in pounds.	Weight of the Vapor in pounds.	Total Weight of Mixture in pounds.			
1	2	3	4	5	6	7	8	9	10	11
0°	.935	.0864	.044	29.877	.0863	.000079	.086379	.00092	1092.4	
12	.960	.0842	.074	29.849	.0840	.000130	.084130	.00155	646.1	
22	.980	.0824	.118	29.803	.0821	.000202	.082302	.00245	406.4	
32	1.000	.0807	.181	29.740	.0802	.000304	.080504	.00379	263.81	3289
42	1.020	.0791	.267	29.654	.0784	.000440	.078840	.00561	178.18	2252
52	1.041	.0776	.388	29.533	.0766	.000627	.077227	.00819	122.17	1595
62	1.061	.0761	.556	29.365	.0747	.000881	.075581	.01179	84.79	1135
72	1.082	.0747	.785	29.136	.0727	.001221	.073921	.01680	59.54	819
82	1.102	.0733	1.092	28.829	.0706	.001667	.072267	.02361	42.35	600
92	1.122	.0720	1.501	28.420	.0684	.002250	.070717	.03289	30.40	444
102	1.143	.0707	2.036	27.885	.0659	.002997	.068897	.04547	21.98	334
112	1.163	.0694	2.731	27.190	.0631	.003946	.067046	.06253	15.99	253
122	1.184	.0682	3.621	26.300	0599	.005142	.065042	.08584	11.65	194
132	1.204	.0671	4.752	25.169	.0564	.006639	.063039	.11771	8.49	151
142	1.224	.0660	6.165	23.756	.0524	.008473	.060873	.16170	6.18	118
152	1.245	.0649	7.930	21.991	.0477	.010716	.058416	.22465	4.45	93.3
162	1.265	.0638	10.099	19.822	.0423	.013415	.055715	.31713	3.15	74.5
172	1.285	.0628	12.758	17.163	.0360	.016682	.052682	.46338	2.16	59.2
182	1.306	.0618	15.960	13.961	.0288	.020536	.049336	.71300	1.402	48.6
192	1.326	.0609	19.828	10.093	.0205	.025142	.045642	1.22643	.815	39.8
202	1.347	.0600	24.450	5.471	.0109	.030545	.041445	2.80230	.357	32.7
212	1.367	.0591	29.921	0.000	.0000	.036820	.036820	Infinite.	.000	27.1

ticularly in connection with an excess of moisture, its presence is always an index of the actual contamination of the air by other impurities. The presence of carbonic acid being easily determined by experiment, the fixing of a certain standard limit of amount in which it may be allowed in ventilated rooms, also limits the permissible vitiation of the atmosphere by other impurities. When carbonic acid is present in excess of 10 parts in 10,000 parts of air, a feeling of weariness and stuffiness, generally accompanied by headache, will be experienced, while even with 8 parts present in 10,000 a room would be considered close. For general considerations of ventilation, the limit should be placed at 6 or 7 parts in 10,000, thus allowing an increase of 3 or 4 parts per 10,000 over that present in outdoor air.

The excessively bad condition of the air in many halls and theatres, is demonstrated by the following results of experiments made by Dr. Angus Smith, in various theatres in London.

PLACE AND TIME.	Parts of Carbonic Acid in 10,000 of Air.
Surrey Theatre, boxes, 10 P. M.	11.1
" " " 12 "	21.8
City of London Theatre, pit, 11.15 P. M. . . .	25.2
Standard Theatre, pit, 11 P. M.	32.0

In these cases injurious effects could not fail to ensue from a continued exposure to such seriously contaminated air.

Amount of Air Required for Ventilation. Under the general conditions of outdoor air, namely 70° temperature and 70 per cent. of complete saturation, an average adult man, when sitting at rest as in an audience, makes 16 respirations per minute of 30 cubic inches each, or 480 cubic inches per minute. Under the previously assumed conditions of 70° temperature and 70 per cent. humidity, the air thus inhaled will consist of about $\frac{1}{5}$ oxygen and $\frac{4}{5}$ nitrogen, together with about $1\frac{7}{10}$ per cent. aqueous vapor and $\frac{4}{100}$ of a per cent. carbonic acid. By the process of respiration the air will, when exhaled, be found to have lost about $\frac{1}{5}$ of its oxygen by the formation of carbonic acid, which will have increased about one hundred fold, thus forming about 4 per cent. while the water vapor will form about 5 per cent. of the volume. In addition the inhaled air will have been warmed from 70° to 90°, and, notwithstanding the increased proportion of carbonic acid,—which is about one and one-half times heavier than air,—will, owing to the increase of temperature and the levity of the water vapor, be about three per cent. lighter than when inhaled. Thus it will be seen that this vitiated air will not fall to the ground, as has often been presumed, but will naturally rise above the level of the breathing line, and the carbonic acid will immediately diffuse itself into the surrounding air. In addition to the carbonic acid exhaled in the process of respiration, about $\frac{1}{5}$ more is given off by the skin. Assuming that an amount of air is supplied sufficient to dilute this to the same proportion as the breath, then, obviously, about 580 cubic inches, or .33 cubic feet of fresh air, is actually required to supply the fixed requirements of the body. But, furthermore, $1\frac{1}{2}$ to $2\frac{1}{2}$ pounds of vapor are evaporated daily from the surface of the skin by a person in still life. If the air supplied at 70° is assumed to have a humidity of 70 per cent. and to be saturated when it leaves the body at a higher temperature, then at least 4 cubic feet of air per minute will be required to carry away this vapor.

Taking into consideration these various factors, it becomes evident that about $4\frac{1}{2}$ cubic feet of air will be required per minute to thoroughly remove from an individual all vitiated air, and to furnish fresh air for respiration and the absorption of moisture from the skin. This, however, is only on the assumption that any given quantity of air, having fulfilled its office, is immediately removed without contaminating the surrounding atmosphere. But from previous considerations, it is seen that the spent air from the lungs is immediately diffused into the atmosphere, and further, that the carbonic acid allowance in indoor air should not exceed 6 or 7 parts in 10,000, whereas, that in the .33 cubic feet of vitiated air removed from the person per minute, is present in the proportion of 400 parts in 10,000. To dilute this .33 cubic foot, so that the carbonic acid shall not exceed 6 or 7 parts in 10,000, there would be required about 19 to 22 cubic feet per minute or 1,140 to 1,320 cubic feet per hour.

These figures may be taken as a fair standard for air when it is supplied directly and positively to the person, and when no modifying influences exist. But almost universally some circumstances will be found to cause a decided departure from these figures. Any motion upon the part of an individual increases the vitiating power of the breath and therefore more fresh air is required to dilute it. Disagreeable odors often arise from the body and clothing, and special vitiating elements may be present, as in hospitals. Furthermore, the amount of air required will always be found to be directly dependent upon its humidity. Among the most important modifying influences, as generally present in large buildings, is the method of illumination. Gas, at the present time the most general illuminant, is in its combustion a large consumer of oxygen from the air. A single $4\frac{1}{2}$ foot burner demands 45 cubic feet of air per minute, and the resulting carbonic acid, unless sufficiently diluted or immediately removed, will seriously contaminate the air. The construction of a building, the size of the rooms, the number of occupants and the time during which a given room is occupied, all have their direct influence. Under all these considerations it is readily seen that no standard allowance can be made to suit all circumstances, and results will be satisfactory only in so far as the designer understandingly, with a knowledge of the various requirements as they have here been given, makes such allowance.

The figures of the celebrated French experimenter, Morin, are here presented as showing the average conditions and allowances in France.

Hospitals for ordinary cases	2,120–2,470	cubic feet.
" " wounded	3,530	" "
" " epidemics	5,300	" "
Prisons	1,766	" "
Workshops, ordinary	2,120	" "
" unhealthy	3,530	" "
Barracks, day	1,060	" "
" night	1,410–1,765	" "
Theatres	1,410–1,765	" "
Large rooms for long meetings	2,120	" "
" " " shorter "	1,160	" "
Schools for children	424–530	" "
" " adults	880–1,060	" "

The best American practice indicates that, under general conditions, an allowance less than 30 cubic feet per head per minute should not be made, and that 45 to 60 cubic feet will be found much more satisfactory. The following statement by Dr. Billings* bears out this assertion. "I certainly do not believe that 30 cubic feet of air per minute in rooms continuously occupied, will secure good ventilation; nor do I think that an architect or engineer is justifiable in preparing plans upon the basis of such an amount of air."

Whatever figures are here given, or opinions expressed, are entirely with relation to *comfortable* ventilation. Anything may be called *tolerable* that is tolerated anything may be esteemed *endurable* that is endured.

Heating.

Heat of Human Body. The normal internal temperature of the human body is very near 100°, independent of the temperature of the surrounding air. By respiration the continuous process of slow combustion is kept up, — the oxygen of the air, uniting with the carbon of the blood passing through the lungs, to form carbonic acid. As in any case of combustion overheating takes place unless provision is made for the distribution of the heat generated, so the body is kept at its normal temperature only by the abstraction of heat from it. The actual *heating* of the body is not the ultimate object of heating; but, in reality, provision is made for the abstraction of the heat generated by the vital functions without making too great a demand upon the physical endurance of the individual.

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* Ventilation and Heating: John S. Billings, M. D., LL. D. (Edinb.)

Means of Dispersion of Heat. Three means are provided for the healthful dispersion of heat from the human body. 1st. By radiation to the air and surrounding objects. 2d. By conduction, principally to the air immediately in contact with the body. 3d. By evaporation of moisture from the lungs, throat and skin. Under the conditions of summer air, the last two are generally about equal, but the greater part of the heat is dissipated by the first means. Air is a nearly perfect non-conductor of heat, but radiation takes place through it readily. We may enter a room having a temperature of 75°, with walls at 50°, and feel chilled, simply because heat is rapidly radiated from the body through the air to the colder walls. In comparatively dry air equality of temperature is kept up by a steady but imperceptible evaporation from the skin. In moist air this rapid evaporation is prevented and the water is deposited as perspiration, the air being too heavily laden to take it up. On the other hand, when the air is in motion it increases both evaporation and conduction by the constant bringing of fresh air to take the place of that already moistened or heated. If, under any circumstances, one of these three means fails to abstract heat rapidly enough, the removal by the other means is increased and equilibrium of temperature kept up.

High humidity has the effect of modifying very materially the temperature at which comfort may be secured. The excessive humidity of the atmosphere of the West and South of England has, owing to the reduced evaporation from the body, the effect of making a temperature of 56° in that country equally as comfortable as 80° in the dryer climate of Canada or Minnesota.

In this country, where some means of heating is usually required during about seven months of the year, the amount of heat necessary and the economy exercised in supplying it are vital questions. Economy can best be secured by a union of the heating and ventilating systems.

Systems of
Ventilation and Heating.

Natural Methods. The requirements of good ventilation and heating being understood, the best method or arrangement for carrying out such requirements presents itself. This will be found to be the stumbling-block over which many an architect and engineer has tripped. Natural agencies, as apparently the least expensive, have usually been first called upon to produce such currents and move such volumes of air as might be required. But it will be admitted on all hands that all systems of "natural ventilation" have proved themselves inadequate to fulfill all requirements. A dependence upon windows and doors for ventilation, cannot, with propriety, be called a system of ventilation, for the supply is ordinarily spasmodic, and, without question, disagreeable, except in so far as a cold draught of fresh air from an open window may be preferable to the vitiated and odorous air of a confined apartment. Excellent results may continue for a number of days during the employment of a method of ventilation dependent upon natural agencies, but a change in the temperature or humidity, or in the direction and force of the wind, may exactly reverse the action of the system. Flues, which were designed to furnish fresh air, will be found to be actionless, while foul air ducts may be bringing the foul air from other rooms. So, too, although to a lesser degree, in the case of currents induced by heated surfaces, steam or air jets. Above all, these latter arrangements will be found to be excessively expensive when the power required to develop this movement is taken into account. All such systems are entirely unequal to the task of supplying air in such quantity as has been shown to be required, — above all, they are not positive.

Forced Circulation. In the system of forced circulation by means of that universally adopted machine, — a fan or blower, — the action is *absolute* and *positive*. The whole matter cannot be better expressed than in the words of the late Robert Briggs,* a man of large experience in practical ventilation and heating: "It will not be attempted at this time to argue fully the advantages of the method of supplying air for ventilation by impulse through mechanical means, — the superiority of forced ventilation, as it is called. This mooted question will be found to have been discussed, argued and combated on all sides, in numerous publications, but the conclusion of all is, that if air is wanted in any particular place, at any particular time, it must be put there, not allowed to go. Other methods will give results at certain times or seasons, or under certain conditions. One method will work perfectly with certain differences of internal and external temperatures, while another method succeeds only when other differences exist. One method reaches to relative success whenever a wind can render a cowl efficient. Another method remains perfect as a system if no malicious person opens a door or window. No other method than that of impelling air by direct means, with a fan, is equally independent of accidental natural conditions, equally efficient for a desired result, or equally controllable to suit the demands of those who are ventilated."

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* On the Ventilation of Halls of Audience. Robert Briggs; Proc. Am. Soc. Civil Engineers, May, 1881.

Efficiency of the Fan. Further on in the same paper, Mr. Briggs states that — "In all mechanical appliances, that is simplest which most positively and directly effects the purpose in view; and in this matter of supplying air, it may be claimed that the process of impelling it, when and where wanted, is at once the most certain and efficient, and that the fan (in its form of a rotating wheel with vanes for large uses) is the simplest and readiest machine for impelling air. It will not be attempted at this time to discuss the theory of Rotary Fans. The fan itself will simply be accepted as one of the recognized appliances in the construction of ventilating apparatuses, available with other mechanisms in established forms and defined types for American practice."

After showing the enormous expense of moving air by allowing it to pass over steam-heated surfaces (thus creating a difference in pressure due to a difference in temperature) compared with the expense of moving equal quantities of air by means of a fan, Prof. S. H. Woodbridge,* of the Massachusetts Institute of Technology, states that "among the many mechanical devices for the movement of air through channels, none are so economical of power and convenient in use as the fan." Such evidence, in conjunction with the personal experience of many users, must be sufficient to convince anyone of the perfect adaptability of the fan as a means of moving and forcing air for ventilation.

Methods of Heating. In the progress of civilization more efficient arrangements for heating have gradually been adopted. Fireplaces, stoves and furnaces have, in the order named, been introduced as means of warming. For small rooms, as in dwellings, they answer very well; but the effect of opening or closing windows and doors and of changes in the atmospheric conditions is too well appreciated to need recital here. It will certainly be admitted that a building can seldom be found where the heated air is *properly* and *satisfactorily* furnished and distributed by a furnace: some of these influences are sure to act, and at times it will be impossible to heat certain rooms without the closing of doors or shutting of registers in other rooms. Hot water apparatus has also laid claim to public favor during the past few years. But steam heating, either direct, indirect, or mixed, is by all means the most satisfactory.

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* Notes on Ventilation and Heating: Prof. S. H. Woodbridge, Mass. Inst. Tech., Boston, Mass.

Ventilation and Heating Combined. All these methods of heating make no adequate provision for supplying the proper amount of air for ventilation. Especially in schools, churches, theatres, legislative chambers and all halls of audience do such systems of heating fail, because of the lack of fresh air provided. In this climate, where heating is a necessity during the greater part of the year, and where, it must be admitted, ventilation is too often considered as a luxury, there is but one system of ventilation and heating that can be employed with assurance of success. Such is the combined system of forced circulation by means of a fan and indirect steam heating, also known as the "System of Hot Air Heating and Ventilation" and as "Heating and Ventilating by the Blower System," but more familiarly by the title, "Sturtevant System"; for B. F. Sturtevant, of Boston, Mass., was the pioneer both in the introduction and manufacture of the apparatus employed in this system. His first patent was issued nearly twenty years ago, and he has for a quarter of a century been so closely connected with the extensive introduction of the system throughout the country that the latter title has been generally adopted as the natural and most explanatory one. The system is at once practical, successful and economical, for air being the natural conveyor of heat to the body, it performs the double office of warming and ventilating. Application may be made in two ways: either by exhausting the air from or forcing it into an apartment. The former is known as the vacuum or exhaust method and the latter as the plenum or pressure method.

The Exhaust Method. There are many objections to the adoption of the exhaust method in this country and as a rule it should be avoided. When exhausting, a partial vacuum is created within the apartment and all currents and leaks are inward; there is nothing to govern definitely the quality and place of introduction of the air and it is difficult to provide proper means for warming it. Under this system provision is often made for drawing the air across steam pipes placed opposite windows, with the expectation that the air will become thoroughly heated in passing across them. Such often fails to be the case, for the most direct course is taken by the air toward the existing vacuity and only a portion of the heating surface is utilized.

The Plenum Method. On the other hand, when the air is forced in, its quality, temperature and point of admission are completely under control; in a word, the method is *positive;* all spaces are filled with air under a slight pressure and the leakage is outward, preventing the drawing of polluted air into the room from any source. But above all, opportunity is given for properly tempering the air by means of heaters, either in direct communication with the fan, or in separate passages leading to the rooms. On the condition that a certain amount of air shall always be supplied, the temperature of it may be varied in two ways. 1st, by varying the amount of heating surface in the heater to which steam is admitted; or, 2d, by keeping the steam supply the same and allowing a portion of the air to "by-pass," or pass around outside of the heater to the fan and there be received at its natural temperature. In places where there is a surplus of waste heat, as in the gases from boiler furnaces, the air for ventilation may be circulated around tubes through which the hot gases are allowed to pass.

Although more fully explained farther on, it may here be stated that there is a most marked saving in heating surface when a system of indirect radiation is used in connection with a fan in place of the ordinary method of direct radiation.

Calculations of Heating Capacity. The thermal value or heating power of water and of steam has been found by elaborate experiments, and the results are embodied in complete and convenient tables. By a proper understanding and use of such tables in connection with tables of the properties of air, ready calculations may be made in all matters relating to steam heating. The following tables, No. 2, Of the Properties of Saturated Steam, and No. 3, Of the Number of Thermal Units Contained in One Pound of Water, embody the principal data. Table No. 1, Of the Properties of Air, Vapor and Saturated Mixtures of Air and Vapor, has already been given. The three will fulfil the general requirements of calculations upon steam heating. Figures between those given in the tables may be obtained with sufficient accuracy by interpolation.

It is customary to base calculations of heating capacity upon the number of pounds or cubic feet of air that can be heated by the condensation of one pound of steam. The specific heat of air under constant pressure is .2379 compared with water as a standard. That is to say, the heat absorbing power of air is about one-fourth that of water, and the amount of heat required to heat one pound of water through 1° F. will heat $\frac{1}{.2379}=4.2034$ pounds of air through the same increment. The total heat and sensible temperature of steam increase with the pressure, as seen by Table No. 2. Upon condensation, steam gives up its latent heat and is resolved into water having the same temperature as the steam from which it was condensed. This water is, in heaters, ordinarily cooled to at least boiling point (212° F.) before being discharged. Hence, the heating power of a pound of steam of a given pressure is expressed by the heat thus given out, *i. e.*, by the total number of units of heat in the original steam less the number in the final water of condensation.

Table No. 2.

Of the Properties of Saturated Steam.

Total Pressure per square inch measured from a Vacuum.	Temperature in Degrees Fahrenheit of Steam and of the Water from which it was evaporated.	Number of British Thermal Units contained in one pound, reckoned from Zero Fahrenheit.		Weight of one Cubic Foot in decimals of a pound.	Volume of one pound of Steam in Cubic Feet.	Relative Volume or Cubic Feet of Steam from one Cubic Foot of Water.
		Number required for evaporation, known as latent heat, or heat of vaporization.	Total number contained in the Steam.			
1	2	3	4	5	6	7
1	102.	1042.96	1145.05	.0030	330.36	20620.
2	126.27	1026.01	1152.45	.0058	172.08	10720.
3	141.62	1015.25	1157.13	.0085	117.52	7326.
4	153.07	1007.23	1160.62	.0112	89.62	5600.
5	162.33	1000.73	1163.45	.0137	72.66	4535.
6	170.12	995.25	1165.83	.0163	61.21	3814.
7	176.91	990.47	1167.90	.0189	52.94	3300.
8	182.91	986.25	1169.73	.0214	46.69	2910.
9	188.32	982.43	1171.37	.0239	41.79	2607.
10	193.24	978.96	1172.88	.0264	37.84	2360.
12	201.96	972.80	1175.54	.0313	31.95	1988.
14	209.56	967.43	1177.85	.0361	27.63	1722.
14.7	212.	965.7	1178.60	.0380	26.36	1644.
16	216.30	962.66	1179.91	.0413	24.21	1514.
18	222.38	958.34	1181.76	.0462	21.64	1350.6
20	227.92	954.41	1183.45	.0511	19.57	1220.3
22	233.02	950.79	1185.01	.0561	17.83	1113.5
24	237.75	947.42	1186.45	.0610	16.39	1024.1
26	242.17	944.28	1187.80	.0658	15.19	948.4
28	246.33	941.32	1189.07	.0707	14.14	883.2
30	250.24	938.92	1190.26	.0755	13.25	826.8
32	253.95	935.88	1191.39	.0803	12.45	777.2
34	257.48	933.37	1192.47	.0851	11.75	733.5
36	260.83	930.97	1193.49	.0899	11.11	694.5
38	264.05	928.67	1194.47	.0946	10.56	659.7
40	267.12	926.47	1195.41	.0994	10.06	628.2
42	270.07	924.36	1196.31	.1041	9.59	599.3
44	272.91	922.32	1197.18	.1088	9.18	573.7
46	275.65	920.36	1198.01	.1134	8.82	550.4
48	278.30	918.47	1198.82	.1181	8.47	529.0
50	280.85	916.63	1199.60	.1227	8.15	508.5
52	283.33	914.86	1200.35	.1274	7.85	490.1
54	285.72	913.13	1201.09	.1320	7.58	472.9
56	288.05	911.46	1201.80	.1366	7.32	457.0
58	290.32	909.83	1202.49	.1411	7.08	442.4
60	292.52	908.25	1203.16	.1457	6.86	428.5
62	294.66	906.70	1203.81	.1502	6.66	415.6

Table No. 2.—Continued.

1	2	3	4	5	6	7
64	296.75	905.20	1204.45	.1547	6.46	403.5
66	298.79	903.73	1205.07	.1592	6.28	392.1
68	300.78	902.30	1205.68	.1637	6.10	381.3
70	302.72	900.90	1206.27	.1682	5.95	371.2
72	304.62	899.53	1206.85	.1726	5.80	361.7
74	306.47	898.19	1207.41	.1770	5.65	352.6
76	308.29	896.88	1207.97	.1814	5.51	344.1
78	310.07	895.59	1208.51	.1858	5.34	336.0
80	311.81	894.33	1209.04	.1901	5.26	328.3
82	313.52	893.09	1209.56	.1945	5.14	320.9
84	315.19	891.88	1210.07	.1989	5.03	313.9
86	316.84	890.69	1210.58	.2032	4.92	307.2
88	318.45	889.52	1211.07	.2075	4.82	300.8
90	320.04	888.38	1211.55	.2118	4.72	294.7
92	321.60	887.25	1212.03	.2161	4.63	288.9
94	323.13	886.14	1212.49	.2204	4.54	283.3
96	324.63	885.04	1212.95	.2245	4.44	278.0
98	326.11	883.97	1213.40	.2288	4.37	272.8
100	327.57	882.91	1213.85	.2330	4.29	267.9
105	331.11	880.34	1214.93	.2434	4.11	256.5
110	334.52	877.86	1215.97	.2538	3.94	246.0
115	337.81	875.47	1216.97	.2640	3.79	236.3
120	340.99	873.15	1217.94	.2743	3.65	227.6
125	344.07	870.90	1218.88	.2843	3.52	219.7
130	347.06	868.73	1219.79	.2942	3.40	212.3
135	349.95	866.62	1220.68	.3040	3.29	205.4
140	352.77	864.57	1221.53	.3139	3.19	199.0
145	355.50	862.57	1222.37	.3239	3.09	193.0
150	358.16	860.62	1223.18	.3340	2.99	187.5
155	360.75	858.73	1223.97	.3430	2.91	182.3
160	363.28	856.87	1224.74	.3521	2.84	177.3
165	365.74	855.06	1225.49	.3615	2.76	172.8
170	368.16	853.29	1226.23	.3709	2.69	168.4
175	370.51	851.57	1226.95	.3799	2.63	164.4
180	372.82	849.87	1227.65	.3889	2.57	160.4
185	375.08	848.21	1228.34	.3980	2.51	156.9
190	377.29	846.58	1229.01	.4072	2.45	153.4
195	379.45	844.99	1229.67	.4161	2.40	150.1
200	381.57	843.43	1230.32	.4250	2.35	147.1
250	401.07	831.22	1235.73	.5464	1.83	114.
300	418.22	819.61	1240.74	.6486	1.54	96.
350	431.96	810.69	1244.58	.7498	1.33	83.
400	444.92	800.20	1249.09	.8502	1.18	73.

Table No. 3.

Of the Number of Thermal Units Contained in One Pound of Water.

Temperature.	Number of Thermal Units.	Increase.	Temperature.	Number of Thermal Units.	Increase.	Temperature.	Number of Thermal Units.	Increase.
35°	35.000		155°	155.339	5.034	275°	276.985	5.107
40	40.001	5.001	160	160.374	5.035	280	282.095	5.110
45	45.002	5.001	165	165.413	5.039	285	287.210	5.115
50	50.003	5.001	170	170.453	5.040	290	292.329	5.119
55	55.006	5.003	175	175.497	5.044	295	297.452	5.123
60	60.009	5.003	180	180.542	5.045	300	302.580	5.128
65	65.014	5.005	185	185.591	5.049	305	307.712	5.132
70	70.020	5.006	190	190.643	5.052	310	312.848	5.136
75	75.027	5.007	195	195.697	5.054	315	317.988	5.140
80	80.036	5.009	200	200.753	5.056	320	323.134	5.146
85	85.045	5.009	205	205.813	5.060	325	328.284	5.150
90	90.055	5.010	210	210.874	5.061	330	333.438	5.154
95	95.067	5.012	215	215.939	5.065	335	338.596	5.158
100	100.080	5.013	220	221.007	5.068	340	343.759	5.163
105	105.095	5.015	225	226.078	5.071	345	348.927	5.168
110	110.110	5.015	230	231.153	5.075	350	354.101	5.174
115	115.129	5.019	235	236.232	5.079	355	359.280	5.179
120	120.149	5.020	240	241.313	5.081	360	364.464	5.184
125	125.169	5.020	245	246.398	5.085	365	369.653	5.189
130	130.192	5.023	250	251.487	5.089	370	374.846	5.193
135	135.217	5.025	255	256.579	5.092	375	380.044	5.198
140	140.245	5.028	260	261.674	5.095	380	385.247	5.203
145	145.275	5.030	265	266.774	5.100	385	390.456	5.209
150	150.305	5.030	270	271.878	5.104	390	395.672	5.216

Taking a pressure of 86 pounds above vacuum, for instance, the total heat is 1210.58 units (by column 4, Table No. 2), while the heat in one pound of the water of condensation at 212° is 212.9 units (by interpolation in Table No. 3,—for practical purposes, the number of degrees of temperature and the units of heat may be taken to be the same at ordinary temperatures) and the number of units rendered available is 1210.58–212.9=997.68 units. The standard unit of heat is equivalent to the amount of heat necessary to raise the temperature of one pound of water through one degree Fahrenheit at its point of greatest density. Therefore, 997.68 units will heat 997.68 pounds of water 1°, or, owing to the difference in specific heat, this number of units will raise the temperature of 997.68×4.2034=41936.48 pounds of air through 1°. Supposing the air to be originally at a temperature of 62°, then, if dry, its weight per cubic foot would be .0761 pounds (column 3, Table No. 1), and 41936.48 pounds would be equivalent to $\frac{41936.48}{.0761}=55{,}107$ cubic feet.

Upon this basis Table No. 4 has been calculated: it being assumed that the water of condensation is always cooled to 212°. The amount of heat that would thus increase the temperature of the volume of air through one degree would raise the temperature of half the amount through twice as many degrees, and so on, in the same proportion.

As an example of the application of Table No. 4, suppose it is desired to heat 750,000 cubic feet of air from 42° to 72°, or an increment of 30° with steam of 75 pounds absolute pressure. By Table No. 4 it is seen that one pound of steam, at the given pressure, will raise 52,864 cubic feet of air at 42° through 1°, and consequently $\frac{52864}{30}=1762.1$ cubic feet through 30°. To heat 750,000 cubic feet through 30° there will therefore be required $\frac{750000}{1762.1}=425.6$ pounds of steam. If the water of condensation had been cooled to a lower point than 212°, more heat would have been derived from each pound of steam, and, hence, less steam would have been required. This sets forth the importance of cooling such water to as low a temperature as possible.

It will be seen by the horizontal column at the bottom of the table that the presence of vapor, even to saturation, will have but slight effect on these values at low or even moderate temperatures.

Table No. 4.

Of the Number of Cubic Feet of Air that may be Heated through 1° F. by the Condensation of one Pound of Steam, and the Cooling of the Water of Condensation to 212° F.

Steam Pressure above Vacuum.	TEMPERATURE OF AIR.										
	0°	12°	22°	32°	42°	52°	62°	72°	82°	92°	102°
15	46872	48224	49277	50320	51335	52330	53363	54358	55402	56397	57430
25	47270	48634	49696	50748	51783	52775	53817	54820	55863	56876	57919
35	47554	48927	49995	51054	52083	53092	54141	55150	56199	57218	58267
45	47777	49157	50230	51294	52329	53343	54396	55411	56564	57488	58541
55	47965	49349	50427	51494	52531	53550	54608	55528	56684	57712	58770
65	48126	49515	50596	51667	52709	53730	54792	55813	56875	57906	58968
75	48268	49661	50745	51819	52864	53889	54953	55978	57042	58077	59141
85	48396	49793	50879	51957	53004	54031	55099	56126	57193	58231	59298
95	48512	49912	51002	52094	53132	54161	55231	56261	57331	58371	59441
105	48662	50066	51159	52243	53296	54329	55402	56435	57508	58551	59624
Per ct. of above amounts that will be heated 1° if air is saturated.	99.8	99.6	99.4	99.0	98.6	98.0	97.1	96.0	94.5	92.5	90.1

Relative Heating Power of High and Low Pressure Steam. At this point it may be well to call attention to the very slight advantage in the heating power of high over low pressure steam. By the example just cited, the heat units derived from one pouud of steam of 86 pounds absolute pressure, or about 71 pounds actual pressure (the average working pressure of live steam), was seen to be 997.68 when it is condensed and the water cooled to 212°. While at 16 pounds absolute (the general pressure of exhaust steam), under the same conditions, the heat given out is 967.01 units, or 96.9 per cent. of the former. Hence, additional heat per pound of steam is derived to the extent of only about 3 per cent. when high is used in preference to low pressure steam. But another matter that must be considered in connection with this, is the fact, that the condensation per square foot of heating surface is dependent upon the difference of temperature between the steam within and the air outside the heater. Steam, at 86 pounds absolute, has a sensible temperature of 316.8° (column 2, Table No. 2), while that at 16 pounds absolute pressure is but 216.3°. Supposing the air to be at 70°, then the difference between the temperatures of the air and the steam will be 246.8° and 146.3° respectively, and we should expect to condense $\frac{246.8}{146.3}=1.7$ times as much steam of 86 pounds absolute per square foot as of exhaust steam at 16 pounds absolute pressure. This proportion has been very closely borne out in experiment with a certain Sturtevant Heater, in which, with an actual pressure of 75 to 80 pounds, the maximum condensation was almost double that at 1 or 2 pounds actual pressure. But such results will vary according to the construction of the heater, and for ordinary cases the general allowance is 30 to 50 per cent. increase in pipe in the exhaust steam over the live steam heaters.

The steam discharged as exhaust from a steam engine having been paid for to do the work in the engine, should be considered as costing nothing for heating, for, otherwise, it would undoubtedly be thrown away and no benefit derived from it. It should, therefore, by all means be completely utilized, and live steam never used when exhaust steam can be employed in its place without additional cost. The expense of increased radiating surface, occasioned by the use of the latter, is of small account when the great saving in running expense is considered.

Condensation of Steam per Unit of Heating Surface. The really vital question, of the number of pounds of steam of a given pressure that may be condensed per hour per square foot of heating surface, is so dependent upon circumstances that no absolute fixed values can be given. Under the conditions of an open pipe radiator with air surrounding it at an average temperature of 60°, Robert Briggs gives, as the factor accepted by him, a loss of 1.8 units per hour per square foot of heating surface per degree difference of temperature between the steam inside and the air outside. Other writers and investigators give varying values, but that just given will be found to be a fair average. Taking the air temperature at 60° and the temperature of exhaust steam at 216° (nearly), the difference would be 156°, and the number of units given out per hour per square foot of heating surface would be 156×1.8=280.8 units. The latent heat of steam at atmospheric pressure is 965.7 (column 3, Table No. 2), therefore, $\frac{280.8}{965.7}=.29$ pounds of steam would be condensed per hour per square foot of heating surface. A similar calculation gives .44 pounds with steam at 70 pounds gauge pressure. Direct experiments made at the works of B. F. Sturtevant, on a series of pipes exposed to air of about 60° and strung around a room at about three inches from a cold brick wall, showed a condensation somewhat greater than this, but probably due to several modifying influences, particularly that of the cold wall.

An increased circulation of the air about the pipes will naturally result in increased condensation, and as the natural circulation will vary under different circumstances, these calculations can be considered only as approximating the general practice. The greatly increased efficiency of the pipe surface, when the air is rapidly circulated by means of a fan, will be readily perceived. This forms one of the marked merits of the Sturtevant Steam Hot Blast Apparatus; the increased duty per square foot of pipe surface rendering a much smaller heater capable of doing the same work that would be done by a decidedly larger heater, without such circulation. Careful experiments have shown a condensation of 2 to 2½ pounds of high pressure steam, per hour, per square foot of heating surface in the Sturtevant Heater. A very liberal statement would indicate the Sturtevant Heater to be three to five times more efficient than an open pipe radiator. The special advantages arising from this are more fully set forth farther on.

Steam Required to Heat a Given Space. The amount of steam and of radiator surface required to comfortably heat a given space is dependent upon many variables. Most important of all is the difference in temperature between the in-door and out-door air; for the rate of passage of heat through walls is directly proportional to the difference of temperature upon the opposite sides of the wall. The material of such walls of course governs the rapidity of this loss; — under general conditions wooden buildings most rapidly dissipate the heat, and stone next, while brick buildings best retain the heat. Obviously the relative area of window surface materially affects the loss of heat. Further, the amount of wall and window surface, in proportion to the cubic contents of the apartment, the climate, the location, whether high or low, or upon the side of the building subject to the most chilling winds, the pressure of steam, and the method of heating, all have an influence. With such an array of modifying considerations it is evident that no fixed or unalterable rule can be given for heating all buildings. Yet for average conditions, by direct heating with low pressure steam, estimates are generally based upon an allowance of 1 square foot of heating surface to 100 cubic feet of space, with liberal modifications under special conditions. Estimates for heating by the Sturtevant Steam Hot Blast Apparatus are based upon an allowance of 1 square foot of heating surface to from 150 to 600 cubic feet of space, dependent upon conditions already given, and upon the size and construction of the Heater. It is evident that only the result of extended experience in this direction will enable anyone to estimate correctly upon allowances for steam heating.

Distribution of Air. Too much care cannot be taken in the matter of the distribution of air supplied by the system of ventilation here advocated. In halls of audience, where the occupants are at rest, any slight inequality in distribution is noticeable, but in workshops, where the occupants are continually in motion and not in close contact with each other, less care is generally required in the matter. Experiment has shown that a velocity of air less than 19 inches per second is not perceptible to the senses, and that a velocity as high as three feet per second is not objectionable. Hence, especial care should be exercised in order that no current having a velocity of over three feet per second or 180 feet per minute be allowed to come in contact with the body. This naturally requires careful designing of the main and distributing ducts. Systematic supply involves arrangements of ducts and passages, by which the outer air from some chosen point shall be transported to certain desirable mouths of delivery or outlet registers.

Dimensions and Arrangement of Flues. The dimensions to be given these ducts or passages are absolute ones when the quantity of air to be moved shall have been established by the number of persons and their supply, and when the velocity of the movement of the air is determined or accepted. The velocity of movement is limited on one hand by the motive power applied to impel the air, and on the other by practical dimensions accepted in the construction of ducts and passages.

With a given volume of air moved, a low velocity results in very little loss of pressure by friction but requires large passages, while a high velocity entails a decided loss by friction, with a marked decrease in area of passages. Between these two extremes of loss and gain, a fair average must be taken. This may be attained by allowing a velocity of from 600 to 1200 feet per minute for main and distributing ducts. Much higher velocity may be required under some circumstances, as when the apparatus is not large enough for the work.

The loss of pressure and power due to the friction of air passing through smooth metallic pipes is shown by Table No. 5. The difference will be noted between the losses for a given volume of air in the case of the smallest and largest pipes, and the consequent necessity of large passages and low velocities. The calculations in the table are for a pipe 100 feet long. The losses will increase in direct ratio with the length, being twice as much for 200 feet, etc. The loss in passages, other than smooth metallic ones, as here indicated, will be greater in proportion to the roughness of the interior.

Table No. 5.

Of the Power Required (in terms of pressure in ounces per square inch and in horse power) to Compensate for the Friction of Air Passing through Pipes of Different Diameters and at Different Velocities.

Diameter of Pipe in Inches	Loss of Pressure and Horse Power.	VELOCITY OF AIR IN FEET PER MINUTE.									
		200	400	600	800	1000	1200	1400	1600	1800	2000
1	Loss of Pressure in ozs. per sq. in.	.044	.178	.400	.711	1.111	1.600	2.178	2.844	3.600	4.444
	Horse Power lost in Friction.	.0000	.0001	.0004	.0008	.0017	.0029	.0045	.0068	.0096	.0132
6	Loss of Pressure in ozs per sq. in.	.007	.030	.067	.119	.185	.267	.363	.474	.600	.741
	Horse Power lost in Friction.	.0001	.0006	.0021	.0051	.0099	.0171	.0272	.0406	.0578	.0793
12	Loss of Pressure in ozs. per sq. in.	.004	.015	.033	.059	.092	.133	.181	.237	.300	.370
	Horse Power lost in Friction.	.0002	.0013	.0043	.0102	.0198	.0343	.0544	.0812	.1156	.1586
18	Loss of Pressure in ozs. per sq. in.	.002	.010	.022	.040	.062	.089	.121	.158	.200	.247
	Horse Power lost in Friction.	.0002	.0019	.0064	.0152	.0297	.0512	.0816	.1218	.1735	.2380
24	Loss of Pressure in ozs. per sq. in.	.002	.007	.017	.029	.046	.067	.091	.119	.150	.185
	Horse Power lost in Friction.	.0003	.0025	.0086	.0203	.0397	.0685	.1088	.1624	.2313	.3173
30	Loss of Pressure in ozs. per sq. in.	.001	.006	.013	.024	.037	.053	.073	.095	.120	.148
	Horse Power lost in Friction.	.0004	.0032	.0107	.0254	.0496	.0857	.1360	.2031	.2891	.3966
36	Loss of Pressure in ozs. per sq. in.	.001	.005	.011	.020	.031	.044	.060	.079	.100	.123
	Horse Power lost in Friction.	.0005	.0038	.0128	.0305	.0595	.1024	.1632	.2437	.3469	.4759
48	Loss of Pressure in ozs. per sq. in.	.001	.004	.008	.015	.023	.033	.045	.059	.075	.093
	Horse Power lost in Friction.	.0006	.0051	.0171	.0406	.0793	.1371	.2177	.3249	.4626	.6346
60	Loss of Pressure in ozs. per sq. in.	.001	.003	.007	.012	.019	.027	.036	.047	.060	.074
	Horse Power lost in Friction.	.0008	.0063	.0214	.0508	.0991	.1713	.2721	.4061	.5782	.7932

The velocity can be gradually reduced by an increase in the relative area between branches and main passages, and further by the area of outlets, until the final velocity, as it meets the body, does not exceed 180 feet per minute. A safe rule is to make the total area of branches (before they enter the delivery registers, if such be supplied) never less than 25 per cent. in excess of the area of the main passage, and as much greater as may be required to properly reduce the velocity. Outlet flues should be made about one and one-half times the area of supply flues and branches, and placed in such positions as to compel a perfect distribution of the air. If made too small, the air will find other and easier outlets. This may at times be just what is desired in order to prevent all possibility of inward leakage. It is best to group such outlet flues as are near each other into a single flue, but the individual flues should be kept distinct until they have reached some distance from the rooms with which they connect. This will prevent back draughts and cross currents from one room to another. For halls, one final and general eduction flue is best, while for buildings containing a number of rooms, a division of flues will be found advantageous. In either case, the application of an exhaust fan to the exhaust flues will make the action still more positive and increase the velocity in the flues.

Material of Flues. All vertical ventilating flues, ducts or passages should, unless something absolutely prevents, be built into the walls of a building. Horizontal passages on the ground level may be very satisfactorily constructed of brick or stone. They should be clear and unobstructed, and, if large, should not be employed as passageways. Too often, buildings are designed with no reference to proper ventilation, and after a short use the imperative need of some system is felt and wooden or metallic ducts have to be put in. To facilitate the calculation of areas of passages and to show the relative areas of round and square pipes, Table No. 6, Of the Areas of Circles and of the Sides of Squares of the Same Area, is here introduced. If properly built into the walls, the flues should at least be smoothly plastered; or, better still, lined with tin or other metal, or with special tiles, which can be purchased for the purpose. Under the plenum system, here recommended, the fan, heater and engine can be placed in the sub-basement when such exists. The heated air is discharged by the fan into the sub-basement, in which there is thus maintained a slight excess of pressure over that of the external air. The plenum air may be distributed to the various rooms by vertical flues connecting at the bottom with the plenum. Where there is no sub-basement, the air may be conducted to the individual flues by ducts beneath the main floor.

Buildings differ so widely in construction that no standard arrangement of passages, inlets, and outlets is applicable to all forms. The natural direction of the air surrounding the body is upward, owing to its heating by the body. By this circulation the vitiated air is carried upward and dispersed above the breathing line. If natural agencies act in this way, it is at least reasonable to arrange for the admission of air near the floor and for its removal near the ceiling. Such arrangement is found the most satisfactory in large rooms in buildings with equally exposed walls; in some manufacturing establishments, however, the work requires admission at other points. For some rooms having warm inner and cold outer walls successful ventilation is attained by admitting the air above the breathing line through the warm inner wall and allowing it by natural circulation to pass to the cold outer wall where it is cooled, falls to the floor and thence is removed through outlet registers in the warm inner wall near the floor.

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Table No. 6.

Of the Areas of Circles and of the Sides of Squares of the Same Area.

Diam. of Circle in inches.	Area of Circle in square inches.	Sides of Square of same area in square inches.	Diam. of Circle in inches.	Area of Circle in square inches.	Sides of Square of same area in square inches.	Diam. of Circle in inches.	Area of Circle in square inches.	Side of Square of same area in square inches.
1.	.785	.89	11.	95.03	9.75	21.	346.36	18.61
.¼	1.227	1.11	.¼	99.40	9.97	.¼	354.66	18.83
.½	1.767	1.33	.½	103.87	10.19	.½	363.05	19.05
.¾	2.405	1.55	.¾	108.43	10.41	.¾	371.54	19.28
2.	3.142	1.77	12.	113.10	10.63	22.	380.13	19.50
.¼	3.976	1.99	.¼	117.86	10.86	.¼	388.82	19.72
.½	4.909	2.22	.½	122.72	11.08	.½	397.61	19.94
.¾	5.940	2.44	.¾	127.68	11.30	.¾	406.49	20.16
3.	7.069	2.66	13.	132.73	11.52	23.	415.48	20.38
.¼	8.296	2.88	.¼	137.89	11.74	.4	424.56	20.60
½	9.621	3.10	.½	143.14	11.96	.½	433.74	20.83
.¾	11.045	3.32	.¾	148.49	12.19	.¾	443.02	21.05
4.	12.566	3.54	14.	153.94	12.41	24.	452.39	21.27
.¼	14.186	3.77	.¼	159.49	12.63	.¼	461.86	21.49
.½	15.904	3.99	.½	165.13	12.85	.½	471.44	21.71
.¾	17.721	4.21	.¾	170.87	13.07	.¾	481.11	21.93
5.	19.635	4.43	15.	176.72	13.29	25.	490.88	22.16
.¼	21.648	4.65	.¼	182.66	13.52	.¼	500.74	22.38
.½	23.758	4.87	.½	188.69	13.74	.½	510.71	22.60
.¾	25.967	5.09	.¾	194.83	13.96	.¾	520.77	22.82
6.	28.274	5.32	16.	201.06	14.18	26.	530.93	23.04
.¼	30.680	5.54	.¼	207.39	14.40	.¼	541.19	23.26
.½	33.183	5.76	.½	213.83	14.62	.½	551.55	23.49
.¾	35.785	5.98	.¾	220.35	14.84	.¾	562.00	23.71
7.	38.485	6.20	17.	226.98	15.07	27.	572.56	23.93
.¼	41.283	6.42	.¼	233.71	15.29	.¼	583.21	24.15
.½	44.179	6.65	.½	240.53	15.51	.½	593.96	24.37
.¾	47.173	6.87	.¾	247.45	15.73	.¾	604.81	24.59
8.	50.266	7.09	18.	254.47	15.95	28.	615.75	24.81
.¼	53.456	7.31	.¼	261.59	16.17	.¼	626.80	25.04
.½	56.745	7.53	.½	268.80	16.40	.½	637.94	25.26
.¾	60.132	7.75	.¾	276.12	16.62	.¾	649.18	25.48
9.	63.617	7.98	19.	283.53	16.84	29.	660.52	25.70
.¼	67.201	8.20	.¼	291.04	17.06	.¼	671.96	25.92
.½	70.882	8.42	.½	298.65	17.28	.½	683.49	26.14
.¾	74.662	8.64	.¾	306.36	17.50	.¾	695.13	26.37
10.	78.540	8.86	20.	314.16	17.72	30.	706.86	26.59
.¼	82.516	9.08	.¼	322.06	17.95	.¼	718.69	26.81
.½	86.590	9.30	.½	330.06	18.17	.½	730.62	27.03
.¾	90.763	9.53	.¾	338.16	18.39	.¾	742.65	27.25

When neglect to provide suitable flues in the walls necessitates the use of sheet metal piping, either galvanized or black iron may be employed. The former has the advantage of a non-rusting surface, while the black iron is slightly cheaper but will rust if greatly exposed to moisture. Galvanized iron is generally preferable, and is recommended by this house as the best and most serviceable. In any form of passage for air, sudden enlargements and contractions should be avoided, and all bends in, and outlets from, the ducts should be of large radius, as shown in Fig. 2, in order to reduce the loss always resulting from sudden changes in the direction of air in motion. Connections should never be made at right angles, but the direction of motion should be gradually changed. Fig. 3 illustrates the proper manner of taking out a branch from a horizontal brick duct, while in Fig. 4 is shown the same arrangement when the passages are of round metallic pipe.

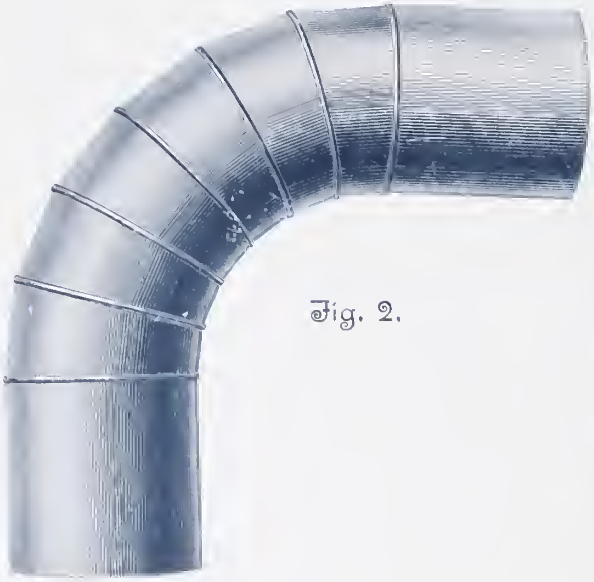


Fig. 2.

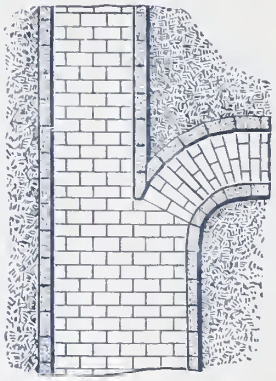


Fig. 3.

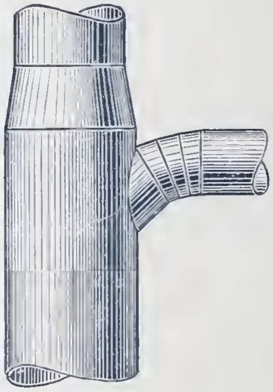


Fig. 4.

In either case, if the branch is of any appreciable size, a reduction in the main should be made beyond the branch for the double purpose of maintaining an equality of velocity and of saving the material used in construction.

Weights of Galvanized Iron Pipe. Ready calculation of the amount of iron required for various diameters and lengths of pipe may be made by means of Table No. 7, Of the Weights of Galvanized Iron Pipe, in Pounds, per Running Foot. This table has been carefully prepared by a practical pipe-maker, and may be relied upon as giving the maximum weight. Due allowance has been made for lap and trimmings as well as for rivets and solder. For general ventilating purposes, pipes under 10 in. should be No. 24 gauge; 10 in. to 15 in., No. 22; 15 in. to 24 in., No. 20; and over 24 in., No. 18 gauge. No. 16 gauge may be used for extra heavy pipe, while for light work, gauges lighter than those here given will be serviceable.

This house is prepared to furnish such pipe in any quantity and of the best of material and workmanship. When the customer is at a great distance and freight rates add too much to the cost, the pipe may be made by local parties, to drawings, which will be furnished.

Table No. 7.

Of the Weights of Galvanized Iron Pipe in Pounds per Running Foot.

Diam. of Pipe in inches.	GAUGE OF IRON.					Diam. of Pipe in inches.	GAUGE OF IRON.				
	No. 24.	No. 22.	No. 20.	No. 18.	No. 16.		No. 24.	No. 22.	No. 20.	No. 18.	No. 16.
4	1½	1⅝	2	2¾	3¼	28	9½	11⅜	14	18	21½
5	1¾	2	2½	3⅜	4	30	10	12¼	15	19⅜	23
6	2⅛	2½	3	4	4¾	32		13⅛	16	20¾	24⅝
7	2½	3	3½	4⅝	5½	34		14	17	22¼	26¼
8	2⅞	3⅜	4	5¼	6¾	36		15	18	23¾	27⅞
9	3¼	3¾	4½	5⅞	7	38		16	19	24½	29½
10	3½	4	5	6½	7⅝	40		17	20	26¼	31¼
11	3¾	4¼	5½	7	8¼	42			21	28	33
12	4	4⅝	6	7½	9	44			22	29¾	35
13	4¼	5⅛	6½	8⅜	10	46			23	31½	37
14	4⅝	5½	7	9	11	48			24	33¼	39
15	5.	6	7½	9⅝	12	50			25	35	41
16	5½	6½	8	10¼	13	52			26	36¾	43
18	6	7¼	9	11½	14¼	54			27	38½	45
20	6½	8	10	12¾	15½	56			28	40¼	47
22	7¼	8¾	11	14	16¾	58			29	42	49
24	8	9⅝	12	15¼	18½	60			30	43¾	51
26	8¾	10½	13	16½	20						

Methods of Introduction of Air. The most satisfactory solution for the equable distribution of the air entering a room appears to be the method proposed by Dr. Reid for the English House of Commons, which consists of a perforated flooring of cast-iron gratings covered with hemp netting. This insures fresh air, delivered at every point at low velocity. But such an arrangement would hardly be generally applicable. In halls having fixed seats, arranged upon the amphitheatre plan, air can be very satisfactorily distributed through registers in the risers, immediately beneath the chairs, or through perforated pipe registers placed at the outer angle formed by the riser and tread.

The entire matter, of the proper arrangements of apparatus and means of distributing the air under diverse conditions, is very fully explained in the latter portion of this work.

Designing of Ventilating and Heating Systems. It is an exceedingly venturesome undertaking to design and carry out a complete system of ventilation and heating, without extended experience. The state of the art at the present time is fairly well understood in theory, but very poorly carried out in practice. This condition is the natural result of the attempts made by many inexperienced builders to apply the established principles of ventilation and heating, without due regard to those modifying influences that entirely determine the efficiency of any system. The principles are correct, but the failure results from a misapprehension and misapplication of them.

The house of B. F. Sturtevant has been directly connected with this work for upwards of a quarter of a century. The results of this continued and extensive experience have been applied to the perfection and simplification of the apparatus required for, and the arrangement of, the most successful system of ventilating and heating. This system has been adopted and is here advocated, because it is at once, theoretically, logically and practically *the best*, and we honestly desire to base our business upon the *merits* of the system and apparatus and not upon sharp methods and dealing. We stand now, as we have for years, prepared to undertake the complete and successful ventilation and heating of all buildings. We prefer to take the contracts direct for the entire work, thereby assuming all risk, and removing from the mind of the architect or builder all doubt of the success of the system which he has thus recommended for introduction.

The Sturtevant

Patent Steam Hot Blast Apparatus.

IN the pages immediately following, the endeavor has been made to present, in as concise a form as possible, descriptions and illustrations of the more important and characteristic types of apparatus manufactured by this house, for complete heating and ventilating under all conditions. More detailed descriptions, with dimensions and prices, will be cheerfully furnished upon application.

The component parts of the Sturtevant Patent Steam Hot Blast Apparatus are a Fan Blower or Exhauster, arranged to be run by belt or with a direct connected engine; a Steam Heater, properly arranged for efficiently heating the air as it is forced or drawn across the pipes; and a Steam Trap, for removing from the heater the water of condensation.

Fans.

The Fan. The fan or wheel proper, as constructed for ordinary ventilating purposes, is enclosed in a special case or shell, and consists of wrought iron arms cast into a hub and carrying the floats or blades, which, together with the side plates of the wheel, are constructed of light but strong steel plate. This construction combines the minimum of weight with the maximum of strength and durability, and is especially designed to meet the requirements of a ventilating fan, namely: ability to handle the largest volumes of air, at low pressure, with the least expenditure of power. The wheel is carried by a stiff steel shaft supported in the Sturtevant Patent Brush Oiler Boxes. Constructed with the greatest care, of the best materials, and containing an oil reservoir from which the oil is continuously fed to the journal by the brushes, this box is at once *unheatable*, is capable of universal adjustment, and once filled with oil may be run for weeks without further attention. The case or shell of the fan is constructed in a great variety of forms to suit all circumstances.

The "Monogram" Pattern. The "Monogram" Exhauster, represented in Fig. 5, is an excellent machine for comparatively heavy work, — the sides and rim being of cast iron. Both bearings are placed upon one side, leaving the inlet upon the other side entirely free for the ingress of air. These fans are built either right or left hand * and with either bottom horizontal discharge, as shown in Fig. 5, or with up blast discharge. Exhausters have an inlet upon one side only; Blowers have both sides open.

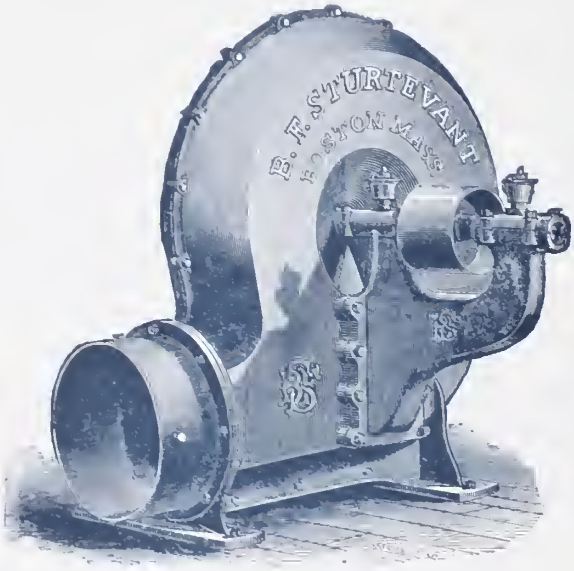


Fig. 5. Monogram Exhauster.
Right Hand, Bottom Horizontal Discharge.

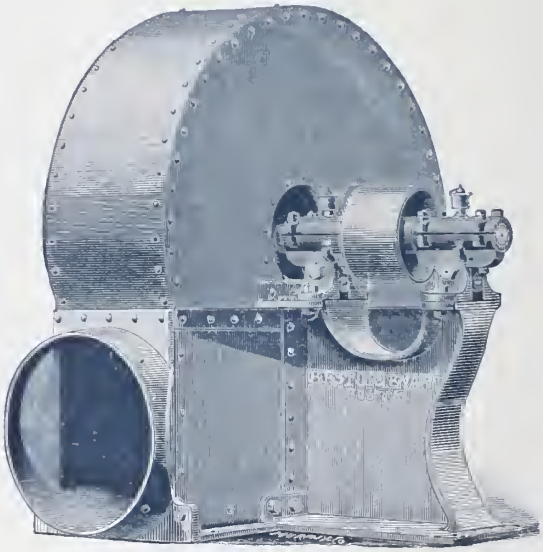


Fig. 6. Steel Plate Exhauster.
Right Hand, Bottom Horizontal Discharge.

Steel Plate Exhausters. A lighter style of exhauster is shown in Fig. 6. This type, known as the Steel Plate, is most extensively employed for ventilating purposes. Its rim and sides are of substantial steel plate, and the entire strain of the belt upon the shaft and wheel is sustained by a broad based standard made of cast iron, resting upon the floor and attached to the exhauster. This style also has both bearings upon the same side, and is built either right or left hand, with bottom, or top horizontal, or up discharge. The Monogram and Steel Plate Fans are built in a large variety of sizes, with inlets and outlets differently arranged as here stated. They are kept constantly in stock, and can be shipped immediately upon receipt of order.

---

* By *right hand* is meant pulley on right hand as one faces the outlet. By *left hand*, pulley on left hand side. In the case of up, down, or oblique discharge, this may be better explained by saying that a Blower or Exhauster is *right hand* when the pulley is on the right hand as the observer stands at the discharge end of the machine.

Steam Fans. In both of the forms just described, power is furnished only by belt from a special engine or from a line or counter-shaft. The following cuts illustrate the manner of connection with a direct connected engine. This latter arrangement is much to be desired under all circumstances where the fan is of moderate or large size. It allows of starting and stopping the fan instantly, independent of any other source of power, and, in many instances, renders unnecessary extensive arrangements of shafting and belting. Furthermore, systems of ventilating and heating are generally applied in buildings, such as theatres, asylums, halls and schools, where there would be little or no other use for an engine. By direct connection, the loss due to slippage and wear of belts is avoided and much less space occupied. The entire apparatus is compact and united, and steam may be supplied from boilers at a distance.

Upon the smaller and more portable sizes of fans the upright engine is usually adopted, while upon the larger sizes, and in connection with independent blast wheels, the horizontal engine is much more satisfactory. Figs. 7 to 10, inclusive, illustrate four different positions of outlet on steam fans of moderate size with direct connected upright engine. The shells of these fans are of stiff steel plate, securely stayed by upright and horizontal deck beams, properly connected to a substantial angle-iron base. In the smaller sizes of steam fans the upright engine is inverted; that is, has its cylinder end up, as seen in Fig. 22, while in the medium sizes the cylinder end is down and is supported by a cast iron bed plate.

This style of fan is especially designed to meet the requirements of ventilating and heating, and as such, is the popular form now applied to that class of work. It is built in the four forms here shown or with special delivery from any point on the periphery of the rim. Obviously, the engine may be placed upon either side.

In the case of large fans, 10 or 12 feet in diameter and upwards, it is often, and usually, advisable to construct a permanent housing wholly or in part of brick. Such arrangements are shown in Figs. 11, 12, and 13. The first cut represents a brick foundation for engine and fan which also forms the lower part of the housing; the upper part, built of steel plate, has a double top horizontal discharge. This arrangement renders unnecessary any sharp return bends in the delivery duct when the air is to be delivered in opposite directions. The style shown in Fig. 12 is convenient and economical of space when it is desired to deliver the air horizontally underground, for a brick duct with branches may be connected with the fan outlet. The upper portion above the bottom of the inlet is built of sheet steel made rigid by the numerous deck beams; a top horizontal discharge of similar construction is shown in connection with a heater in Fig. 24. The air may, by proper arrangement, be delivered in any direction, — horizontally, up, down, or at an angle with these directions. In some instances a housing entirely of brick, as shown in Fig. 13, is found still more substantial and permanent. All directions of discharge are possible as in the other styles. In either of the styles the engine

Steel Plate Steam Fans.

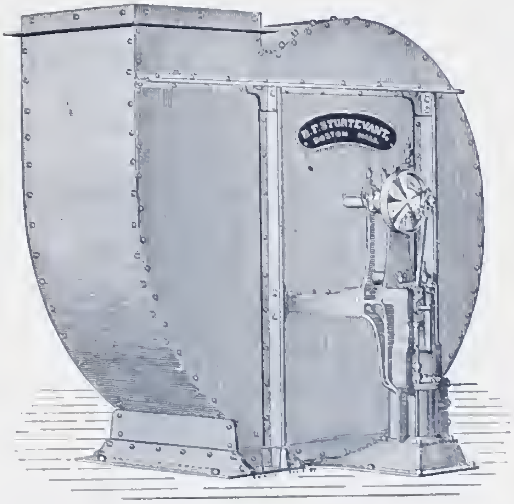

B. F. STURTEVANT, BOSTON MASS.

Fig. 7.
Right Hand, Up Discharge.

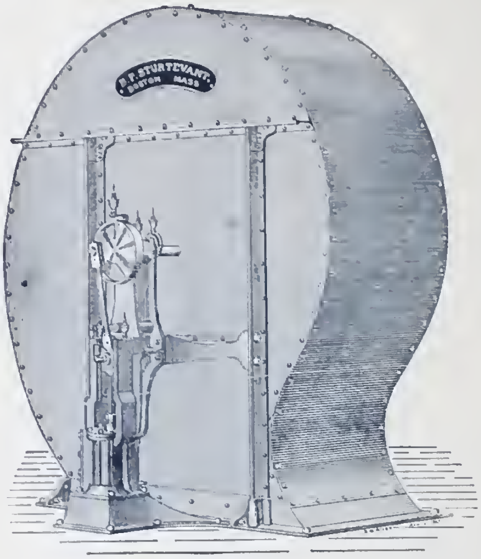

B. F. STURTEVANT, BOSTON MASS.

Fig. 8.
Left Hand, Angular Down Discharge.

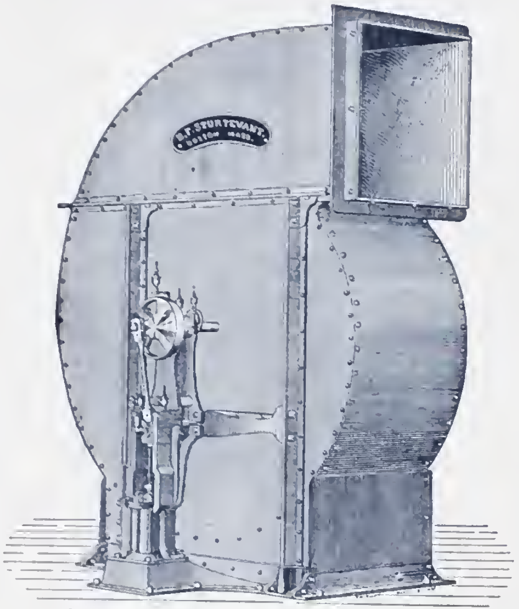

B. F. STURTEVANT, BOSTON MASS.

Fig. 9.
Left Hand, Top Horizontal Discharge.

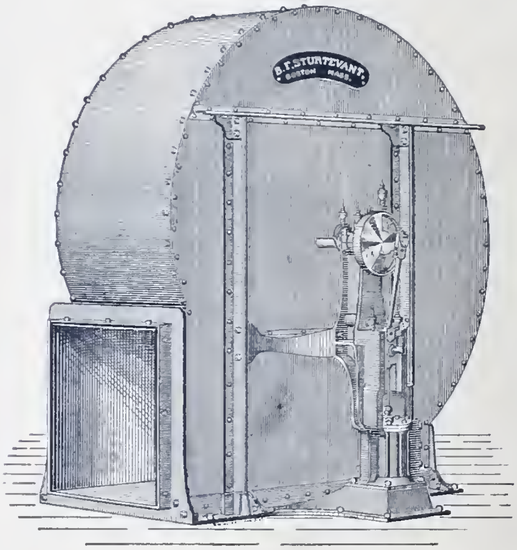

B. F. STURTEVANT, BOSTON MASS.

Fig. 10.
Right Hand, Bottom Horizontal Discharge.

A FEW OF THE

VENEER PRESSES AND GLUE HEATERS

FOR SALE BY

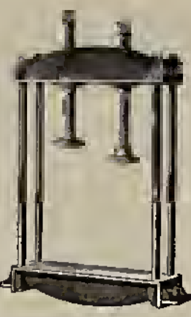
Hammacher, Schlemmer & Co.

ADJUSTABLE SCREW VENEER PRESSES.

Hand Wheel Wrench.

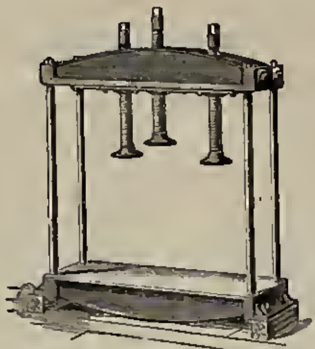
Screw With Nut Flange and Straight Wrench.

Screw 2 in. diameter by 2 ft. long.



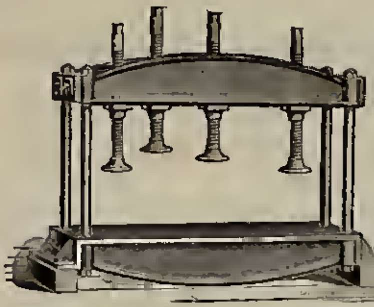
Sectional Presses.

Nos.	Size of Base between Uprights.
1	12 x 9½ inches.
2	18 x 9½ "
3	24 x 9½ "
4	28 x 9½ "
5	32 x 9½ "



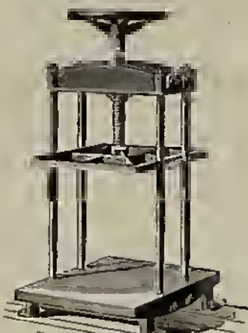
SECTIONAL PRESSES.

Nos.	Size of Base between Uprights
6	38 x 10¼ inches.
7	44 x 10¼ "



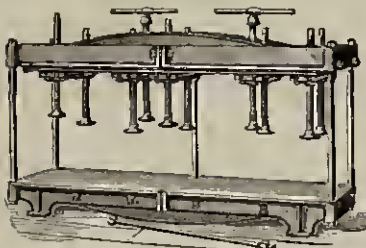
SECTIONAL PRESSES.

Nos	Size of Base between Uprights.
8	53 x 10¼ inches.
9	61 x 13 "



Nos. 12-17 Single Screw Presses

Nos.	Dimensions of Bases.
12	12 x 12 inches.
13	12 x 18 "
14	18 x 18 "
15	18 x 24 "
16	24 x 24 "
17	24 x 30 "

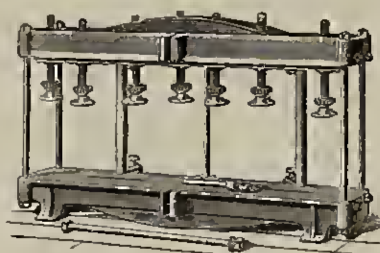


No. 23 COMPLETE PRESS.

PAT. AUGUST [illegible]

Presses of this style made following sizes.

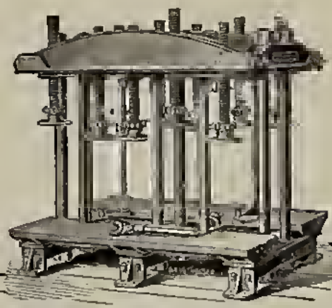
Nos.	Dimensions of Bases.
21	25 inches x 5 feet 4 inches.
22	25 " x 6 " 10 "
23	30 " x 8 " 6 "
24	30 " x 10 "
25	30 " x 12 "



Nos. 30 AND 31 SINGLE PRESSES.

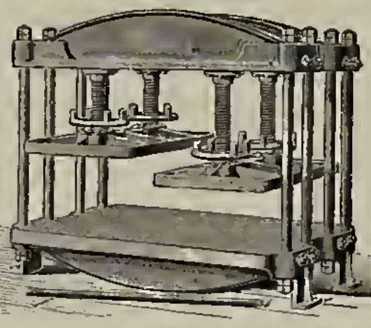
PAT. AUGUST [illegible]

Nos.	Dimensions of Bases.
30	13 inches x 8 feet 6 inches.
31	13 " x 10 "



Nos. 40 AND 41 DOUBLE PRESSES.

Nos.	Dimensions of Base Plates.
40	16 inches x 5 feet.
41	15 " x 6 "



EXTRA HEAVY PRESS.

No. 50, Base 48 x 66 inches with extra heavy screws and plates.

STEAM GLUE HEATERS.

Furnished with or without Stands. Small Glue Cups are Enameled, Larger Sizes Galvanized.

GLUE CUPS.

Enameled or Galvanized, with or without Jackets, as desired.

No. 00,	Capacity,	1 pint.
" 0,	"	1¼ "
" 1,	"	1⅔ "
" 2,	"	2 "
" 3,	"	3 "
" 4,	"	4 "
" 6,	"	5 "
" 6,	"	6 "

No. 1 Glue Heater.

Heaters of this Pattern.

No. 1, with ½-gallon pot.
" 2, " ¾ " "
" 3, " 1 " "
" 4, " 1½ " "

No. 6 Glue Heater.

Heaters of this Pattern.

No. 5, with 2-gallon pot.
" 6, " 2½ " "

No. 6½ Glue Heater.

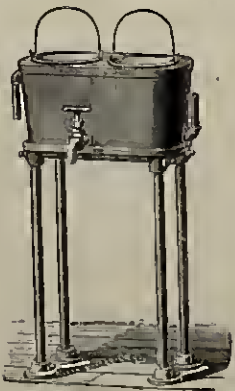
Pots fitted steam tight.

No. 5½ with 2 gallon pot.
" 6½ " 2½ "

No. 96 GLUE BOILER.

Large Size.

Fitted with 25 gallon pot.

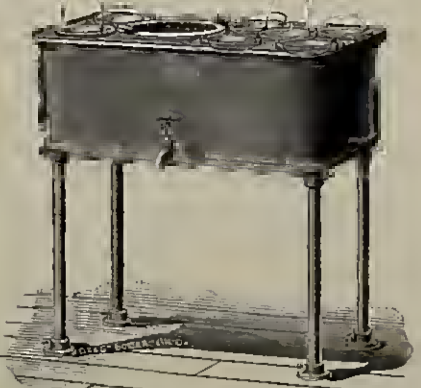


No. 9 Glue Heater.

No. 13 Glue Heater.

No. 15 Glue Heater.

No. 16 Glue Heater.



No. 20 Glue Heater.

Heaters of this Pattern.

No. 9, with two ½-gal. pots.
" 10, " " ¾ " "

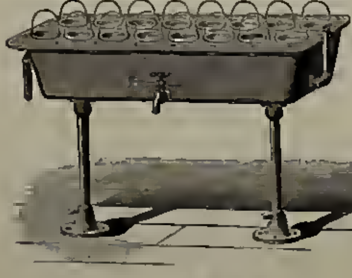
No. 11 with six 1 qt. pots.
" 12 " one 1-gal. & three 1-qt. pots.
" 12½ " one 1½ " " " "

No. 13 with two 2-gal. pots.
" 14 " one 2 gal. & two ½-gal. pots.
" 15 " four ½ gal. pots.

Glue Heaters of this Pattern.

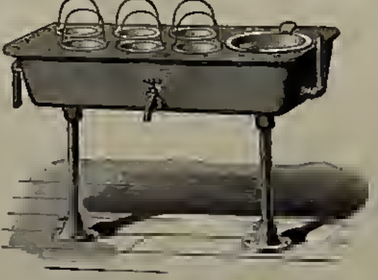
No. 16 with two 4-gallon pots.
" 17 " two 2½ gal. and two ½-gallon pots.
" 18 " six ½-gallon pots.

No. 19 with four 3-qt. and four 1-qt. pots.
" 20 " one 2-gal. and seven 1-qt. pots.
" 21 " one 1½-gal. and six 1-qt. pots.



No. 34 Glue Heater.

With 16 one quart pots.



No 35 Glue Heater.

With one 2½ gallon and six ½ gal. pots.

No. 40 Glue Heater.

Heaters of this Pattern.

No. 36, with galvanized inside tank, 3 ft., 9 inches long.
" 38, " " " " 4 " 9 "
" 40, " " " " 5 " 9 "

No. 41 Glue Heater.

Heaters of this Pattern.

No. 37, same as No. 36 with tank divided in center.
" 39, " " 38 " " " " "
" 41, " " 40 " " " " "

For further particulars and special descriptive circulars and prices, address,

HAMMACHER, SCHLEMMER & CO.,
209 Bowery, NEW YORK.

Steel Plate and Brick Steam Fans.

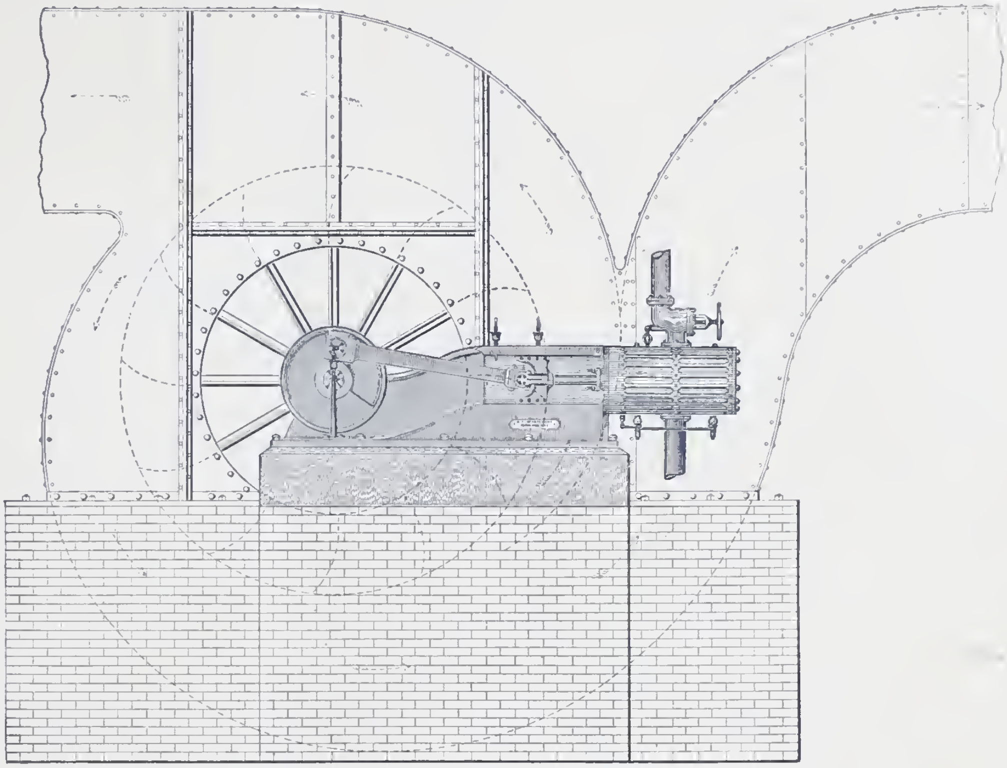


Fig. 11. Top Horizontal, Double Discharge.

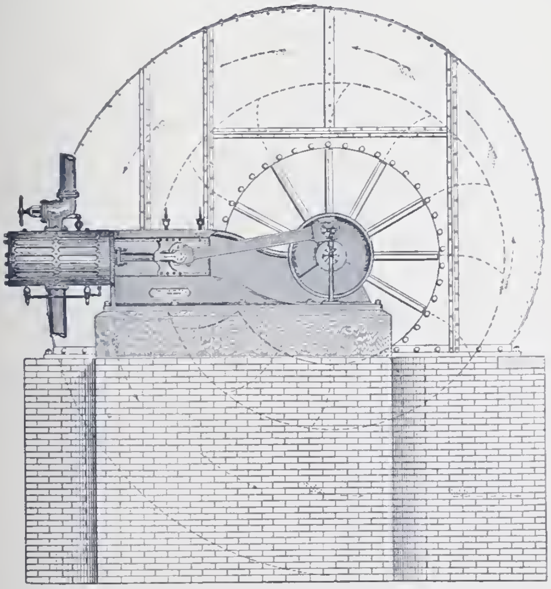


Fig. 12. Left Hand, Bottom Horizontal.

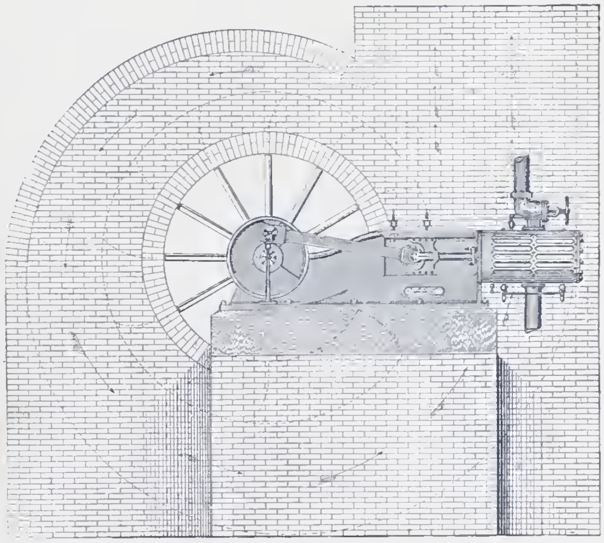


Fig. 13. Left Hand, Up Discharge.

may be built either right or left hand, and placed upon either side of fan, making four different arrangements of engine relatively to fan. In fact, any design can be carried out in the construction of such apparatus, in order to adapt it to all conditions.

Cone Fans. Under certain conditions no housing for the fan is required, and it may be placed so as to run close to a division wall in which an inlet of proper shape and size is provided. The air is thus drawn from one side of the wall and delivered into a space, of greater or lesser extent, upon the same side of the wall with the fan. For such work a fan is constructed somewhat differently from one placed in a regular housing. There is opportunity for considerable variety in design, but Figs. 14 and 15 are presented as types of this class, known as cone fans; built by B. F. Sturtevant. In either type the air is gradually deflected from its course in passing from the inlet to the circumference of the fan; thereby reducing the loss by friction. The air is finally delivered all around the circumference.

When a sub-basement is to be kept filled with air under slight pressure, — as in the plenum system already described, — this fan is very economical and convenient, as no connecting ducts are required, — the fan simply standing in the sub-basement and delivering directly into it. The blades are securely riveted and bolted to the arms, side plates and cone. The latter is of sheet steel, both light and strong, with hubs of cast iron. Additional stiffness is secured in the wide sizes by tie rods, as seen in both figures. The advantages of the cone fan over the ordinary disc or propeller fan are that it will deliver air against resistance, back-lash is impossible, and the centrifugal force of the fan blades is utilized. At a given peripheral speed the cone fan will give superior results in volume of air delivered and in pressure. Size for size they are three times as powerful as the open disc or propeller wheels.

The cone fan illustrated in Fig. 14 is the type built by this house for the ventilation of one of the buildings of the Massachusetts Institute of Technology, Boston, of which a description will be found further on. In this particular case the fan is driven by belt from a line shaft and the air is discharged into a sub-basement. Obviously, the power might have been readily derived from a direct connected steam engine.

Such connection is shown in Fig. 15, which represents another style of cone fan that is quite generally introduced. The engine may be placed upon a solid brick foundation and the outer end of the shaft supported in one of the Sturtevant Brush Oiler Boxes, which latter, in turn, rests upon wrought iron supports. A higher engine foundation would render unnecessary any difference in level on the opposite sides of the wall.

This type of fan is adaptable to all conditions. The division wall may be of any material of proper stability. In small sizes these fans have been placed with the shaft vertical, so as to discharge directly through the floor.

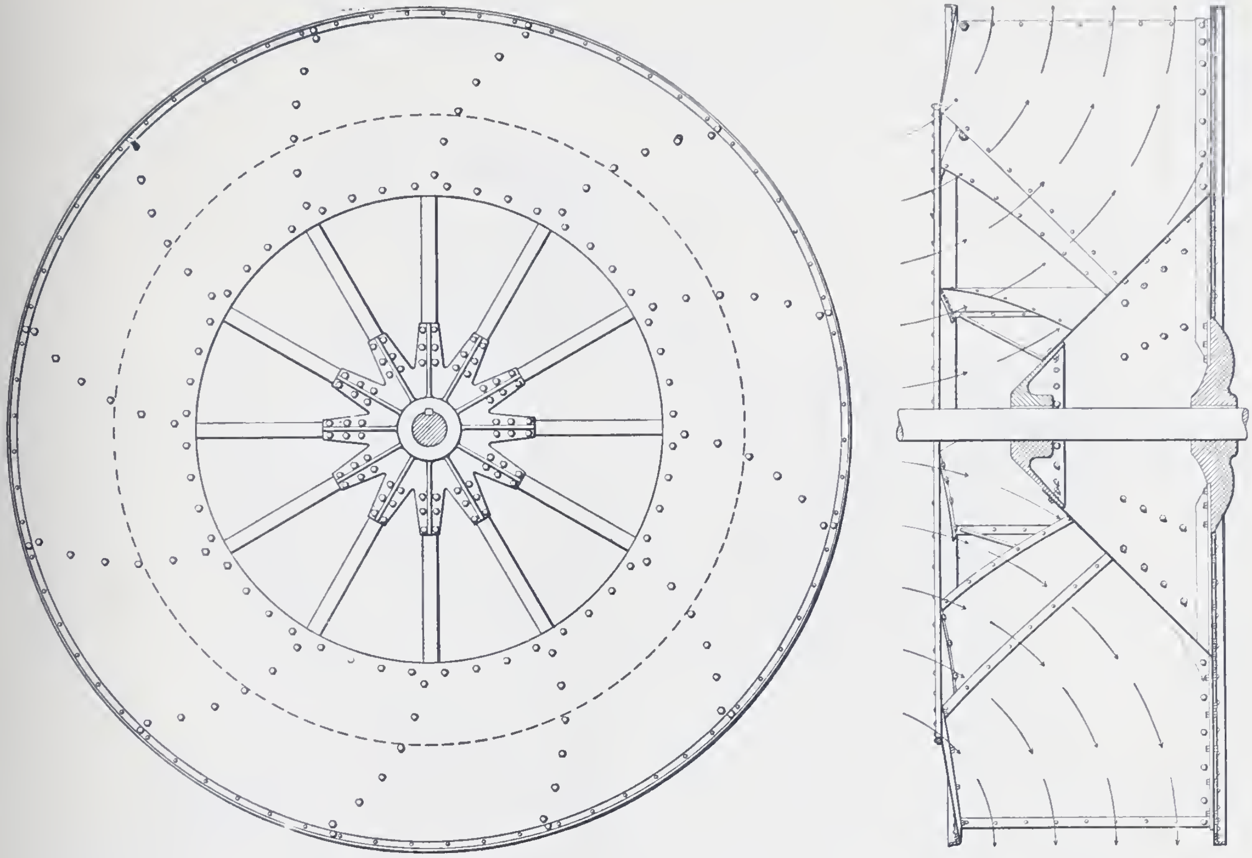


Fig. 14. Cone Fan.

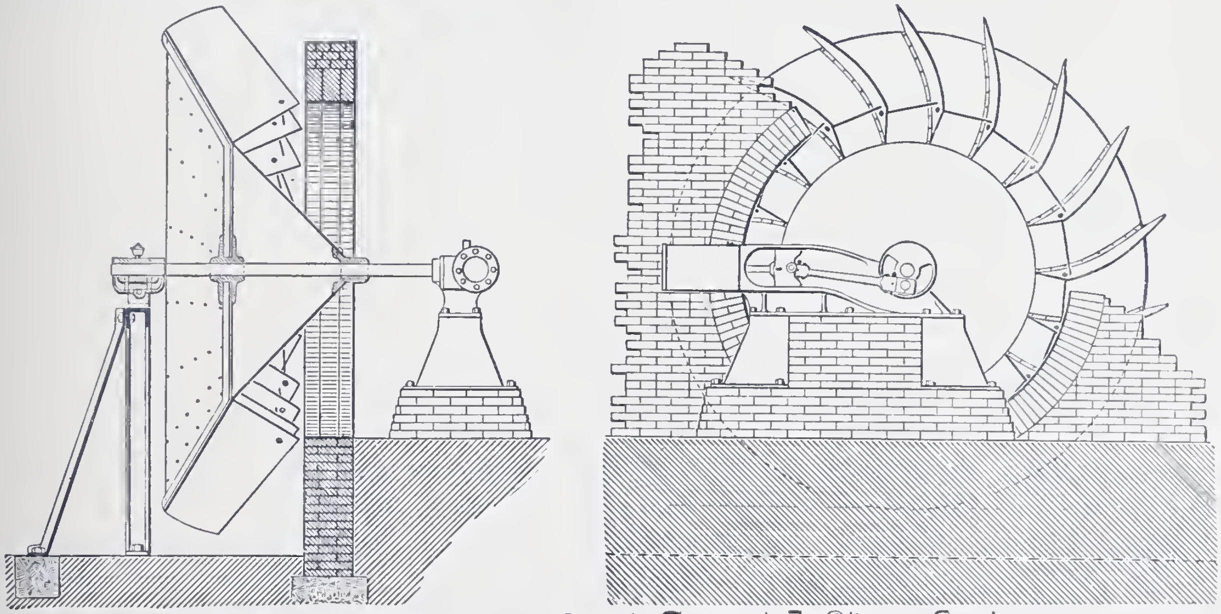


Fig. 15. Cone Fan, with Direct Connected Steam Engine.

Steam Engines.

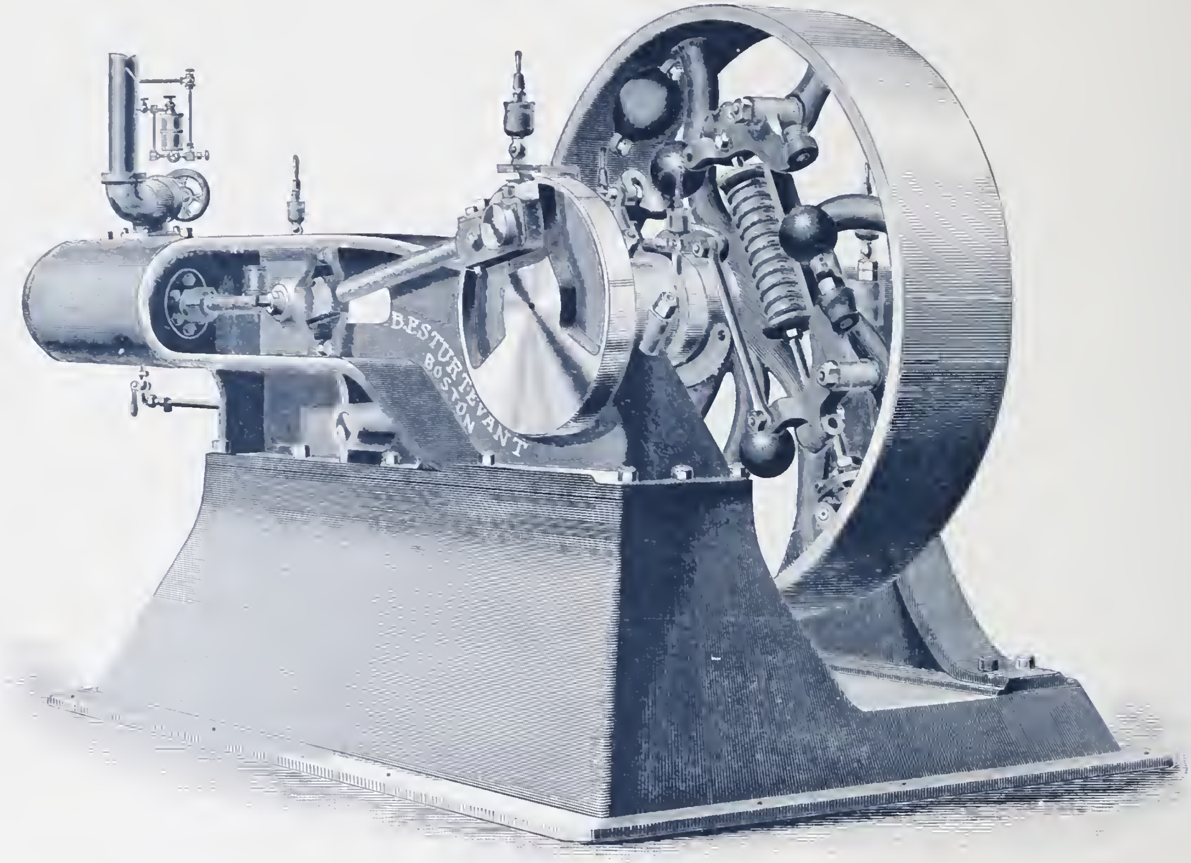


Fig. 16. Sturtevant Automatic Steam Engine.

The Sturtevant Engine. We have patterns for an extensive line of engines, but present here only an illustration of our automatic horizontal high-speed engine of the independent self-contained type. It is simple in construction, the workmanship is first-class, the best of materials are used, and the automatic governor insures perfect regulation under all conditions. In the self-contained patterns both bearings are securely attached to a single bed-plate, making the engine portable and preventing any mis-adjustment after leaving our works. Large sizes of horizontal engines have a separate out-board bearing, and, as well as the smaller sizes, are designed for all classes of work. The fact that we were led into the manufacture of engines to supply the wants of customers who required a first-class engine for fan propulsion, insures due attention having been paid to this class of work. The engines are therefore particularly fitted for fan propulsion, electric lighting, and similar work that requires continuous running at high speeds. When these engines are employed for driving fans, the out-board bearing is usually supported by the fan housing, the engine being placed close to the housing, thus reducing the length of shaft and the opportunity for springing.

The typical forms of upright engines will be seen in connection with the fans illustrated elsewhere. These and the smaller sizes of horizontal engines are kept constantly in stock.

Heaters.

The Heater. This is, in fact, a combination of heaters, each consisting of a single cast-iron section or base into which a triple vertical row of the best wrought-iron pipes is securely screwed. These pipes, of different lengths, are connected at the top by cross-pipes, as shown in Fig. 17, which represents a Sturtevant sectional base heater with steam trap connected, and inlets and outlets indicated. Each section is tested to 150 pounds hydraulic and 100 pounds steam pressure after the pipes are inserted, thus insuring absolutely tight and unleakable joints. Steam is admitted to the manifold or header shown on the right, and thence passes by connecting pipes to the different sections forming the heater. A diaphragm is cast in the base mid-way of its length, just under the central opening between the pipes, so that all steam admitted at the right-hand end of the section is compelled to pass through the pipe connecting with the other end in order to reach the outlet or trap on the left. This construction insures perfect drainage and circulation, and a positive supply of steam to all parts of the heater, at the same time allowing no opportunity for freezing or hammering. The sections and pipes are made in various lengths so that a given amount of heating surface can be arranged to occupy different areas of floor space and of height. The entire heater is placed upon a substantial angle-iron foundation, and enclosed in a steel jacket, properly provided with an air inlet and outlet, which may be connected with supply pipes and fan. The fan can be so placed as to blow into or draw air from the heater. When necessary, a door is provided in the casing of the latter to allow of oiling

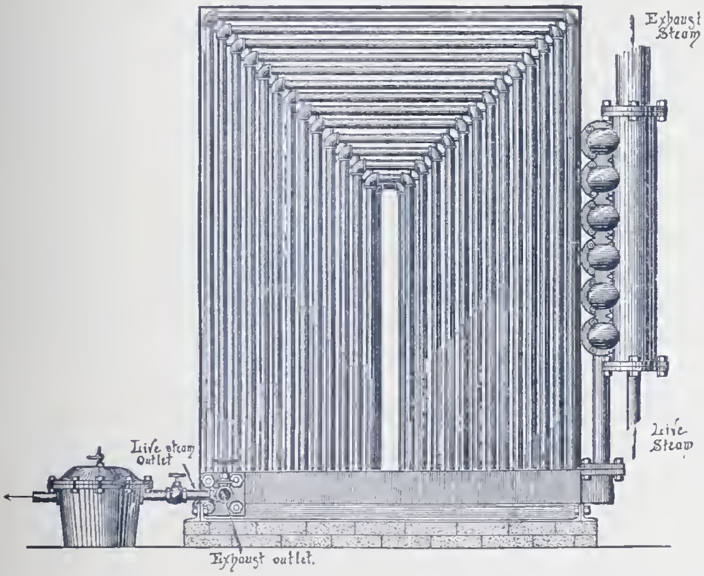


Fig. 17. Sturtevant Steam Heater.

the inner fan-shaft journal. The pipes in the sections are set staggering so that the air currents are completely broken up in passing across them, and every part of the heater acts at its maximum efficiency.

Efficiency of the Sturtevant Heater. The excessively large volume of air, which, by means of the fan, is brought in contact with the pipes of the heater, results in a correspondingly great condensation of steam and transfer of heat. In steam pipes strung around rooms for direct heating, from .3 to .5 pounds of steam are condensed per square foot of pipe surface per hour. The amount of steam condensed is obviously indicative of the amount of heat transmitted to the room, and the larger the condensation per square foot the less pipe is required to give out a stated amount of heat. The Sturtevant Heater has a most marked advantage in this particular, for the rapid change of the air in contact with the pipes results in a very large emission of heat by each square foot of pipe surface.

Direct tests show the Sturtevant Heater, foot for foot, to be three to five times as efficient as ordinary open radiators and coils exposed in open air. In other words, with a given requirement for heating, a saving of at least $66\frac{2}{3}$ to 80 per cent. in pipe can be made by adopting the Sturtevant Patent Steam Hot Blast Apparatus. Furthermore, by its adoption all steam and drip pipes, passing through walls and floors to the various rooms of a building, are done away with, while the labor required in the piping, and the expense of finished work in radiators is avoided. By a mere casual glance at these factors of the cost of a heating plant it will be readily seen that the cost of a Sturtevant Heater will be but a fraction of the expense involved in the purchase and setting up of a complete system of direct steam heating by steam coils.

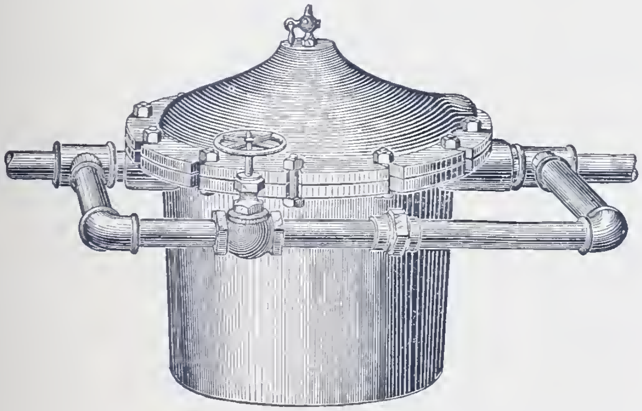
Either live or exhaust steam can be used in these heaters, so that the exhaust from the fan engine may be completely utilized for heating. As previously pointed out, exhaust steam is worth but three per cent. less for heating than high pressure live steam. It is therefore obvious, that if there is but this almost inappreciable loss sustained by the steam in passing through the fan engine, that it costs practically nothing to run the engine, for it is in reality simply an enlargement in the steam pipe leading to the heater.

All danger of fire is avoided in this apparatus, for all the piping is enclosed in the steel jacket entirely independent of all wood-work. Lower rates of insurance are always secured when the heating surface is thus protected.

The Sturtevant Heater possesses the aditional advantage over other forms of heating apparatus in that it may also be used to cool the air passing through it. In summer weather, when the external air is too warm for comfort, cold water or even refrigerating liquids may be circulated through the heater sections, and the air thereby reduced to a comfortable temperature.

Steam Traps.

The Sturtevant Trap. The condensed steam is removed from the Sturtevant Heater by a Sturtevant Steam Trap. This allows of a periodic discharge of the water without the escape of steam. Exterior and sectional views are given in Figs. 18 and 19, respectively. The trap consists of a cast iron body and cover with pipes connecting on either side; the inlet on the left and the outlet on the right. Connection between the interior and the outlet is made through a cored passage in the cover and a hollow brass extension of this passage. At the lower extremity of this extension is an internal conical seat, which is accurately fitted to a brass cone attached to the bottom of the pan. The pan has a cast iron bottom and sheet steel sides, and carries a lattice work brass guide, loosely fitting the brass extension from the cover, which serves to keep the pan upright and insures the perfect seating of the conical surfaces. The trap is so adjusted that when the pan rests upon the bottom of the body the conical seats are not in contact, and a free passage is thus given through the trap from the heater to the outlet. At the top of the cover is a small air cock for removing any accumulation of air in the trap.



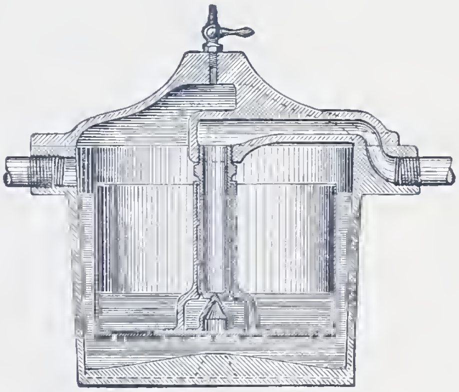


Fig. 18. Sturtevant Steam Traps. Fig. 19.

The action of the trap is as follows: Steam being admitted to the heater, it is rapidly condensed, and the water of condensation flows through the inlet at the left into the space between the pan and the body of the trap. Almost immediately the buoyancy of the pan (which is empty when first set up) causes it to rise until the conical seats come in contact and the passage of steam to the air is prevented. As the water continues to flow in, it gradually fills the space between the body and pan, and finally overflows the edge of the latter. When the amount of water in the pan has increased sufficiently, its buoyancy is overcome, and it sinks until it strikes the bottom. The pressure of steam upon the surface of the water now causes it to pass (through the valve thus opened) into the extension and cored passage, and thence to the outlet pipe at the right. As soon as the pan is nearly empty, it regains its buoyancy, and recloses the valve. It remains thus until again filled, when the water is discharged as before. This action is kept up periodically, the weight of the pan being such that the valve closes before the pan becomes empty, thus preventing all passage of steam.

The outside connecting pipes, shown in Fig. 18, allow of a by-pass for the water and steam without passing through the trap. This, obviously, takes place only when the globe valve is open, which is generally the condition when first starting up the apparatus. These traps are constructed for service with any pressure of steam, and were designed expressly for use in connection with the Sturtevant Heaters.

The Combined Apparatus.

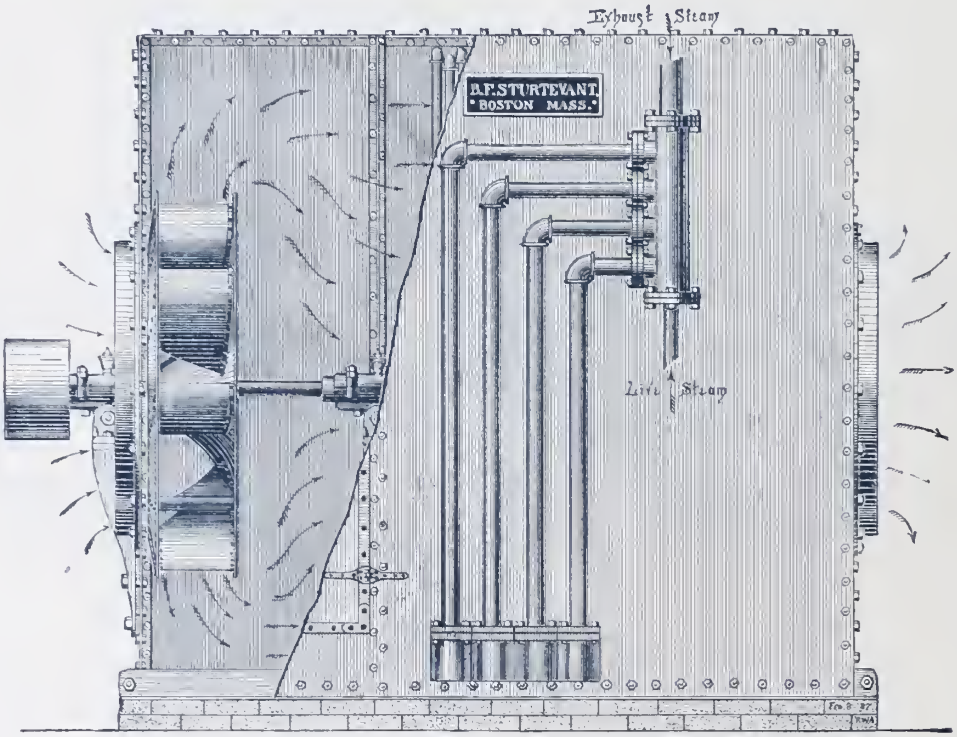


Fig. 20. Cone Fan Heater.

Cone Fan Heater. The simplest arrangement of fan and heater is that shown in Fig. 20, consisting of a cone fan, driven by belt, and a four-section heater. The heater is of the ordinary construction, while the fan is of the cone pattern, properly placed relatively to an inlet in the heater casing. Air is by its means drawn from without and forced into the heater casing, where it is brought into intimate contact with the pipes. It is finally discharged, at the proper temperature, through an outlet to which may be connected pipes for carrying it to distant points. The peculiar advantages of this construction are that it is self contained,—only the pulley extending beyond the casing; and that it is economical, for the casing of the heater serves also all the needs of a casing for the fan; and the latter, being of the cone pattern, moves large volumes of air at a minimum expenditure of power.

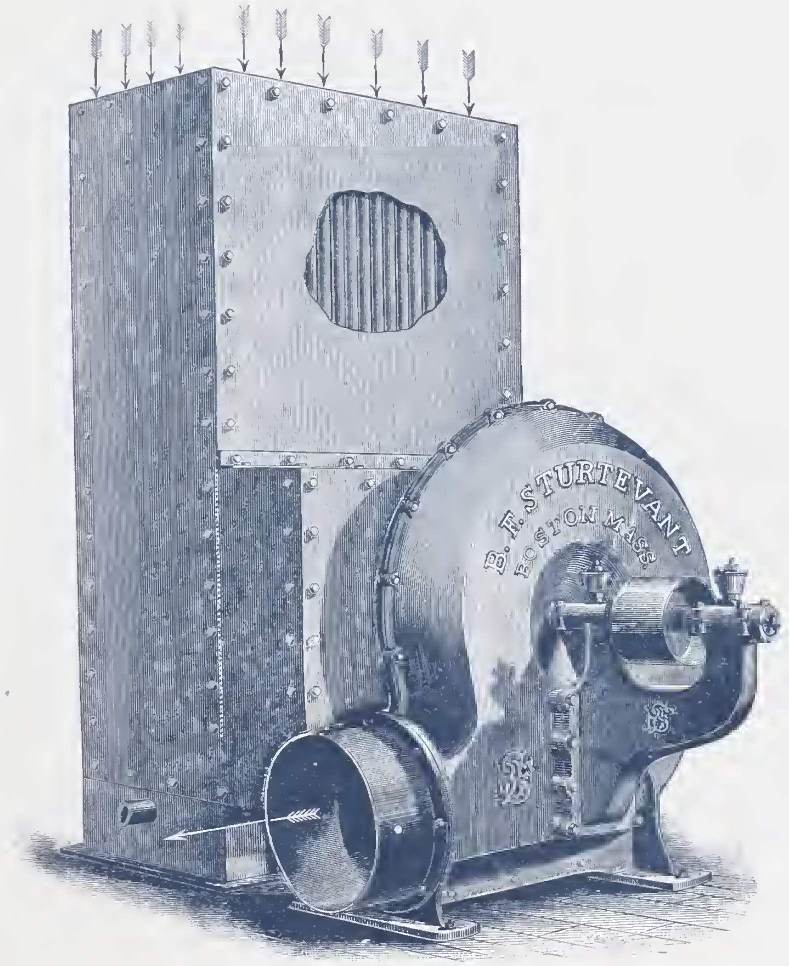


Fig. 21. Monogram Exhauster and Solid Base Heater.

Monogram Exhauster and Solid Base Heater. The simplest combination of independent fan and heater is that illustrated in Fig. 21. The fan is the same as shown in Fig. 5, and is built in the varieties there given. The heater base, as its name indicates, is not in sections, but in a single casting. The distribution of steam, however, is the same as in the sectional heaters; but this form of base is only adopted in the smallest sizes of heaters. Air is taken in and discharged as indicated by the arrows.

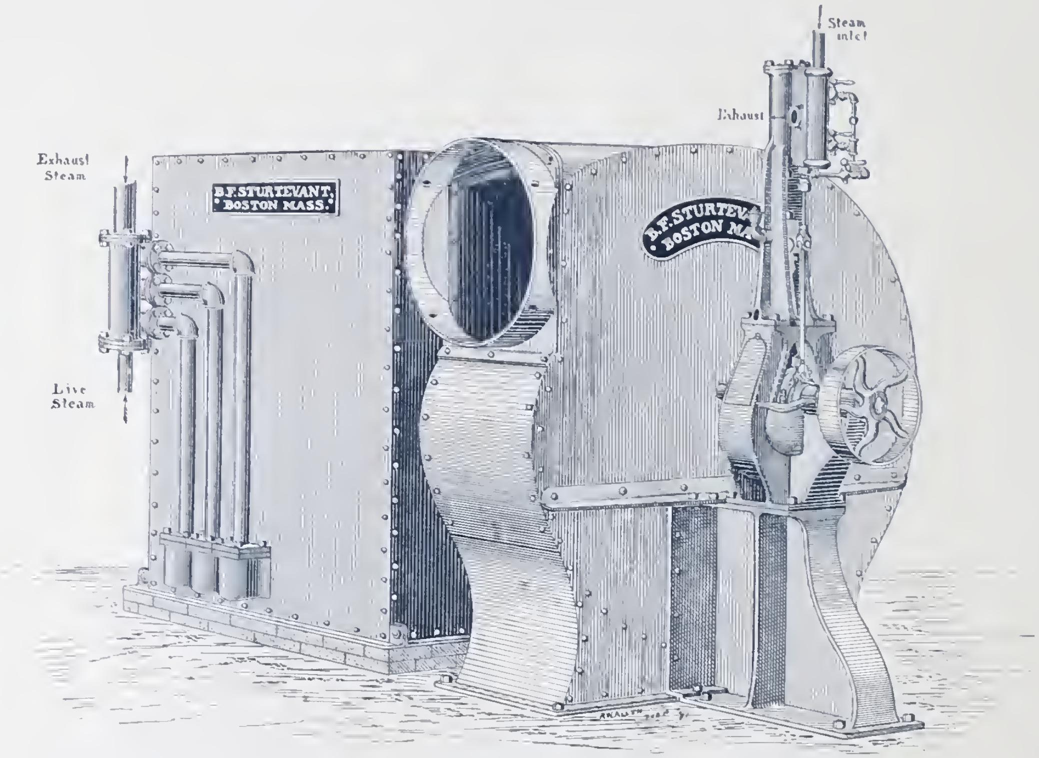


Fig. 22. Steam Hot Blast Apparatus.—Smallest Sizes.

Steel Plate Steam Fan and Heater.—Smallest Sizes. The smallest sizes of steam fans are constructed as shown in Fig. 22. The engine is of the upright inverted pattern; the exhauster is right hand top horizontal discharge, and the heater consists of three sections. The engine is built for high speed; having light running parts, perfectly counterbalanced, and provided with continuous oiling devices. The exhaust from the engine may be discharged into one or more sections of the heater.

The same style of exhauster can be furnished without the engine, and arranged to run by belt, as in Fig. 6. Either the steam or the pulley fan may be right or left hand, bottom or top horizontal, or up discharge. Of course, the number and length of sections and the height of pipes may be almost indefinitely varied to suit all conditions.

Standard Steam Hot Blast Apparatus. The standard Steam Hot Blast Apparatus, for average conditions, is shown in Fig. 23. The upright engine, which in this case has the cylinder end down, is an exceptionally stiff, well built and durable engine. It stands upon a cast-iron bed attached to the fan. The fan shell is substantially stayed by deck beams and direct connection is made between them and the engine.

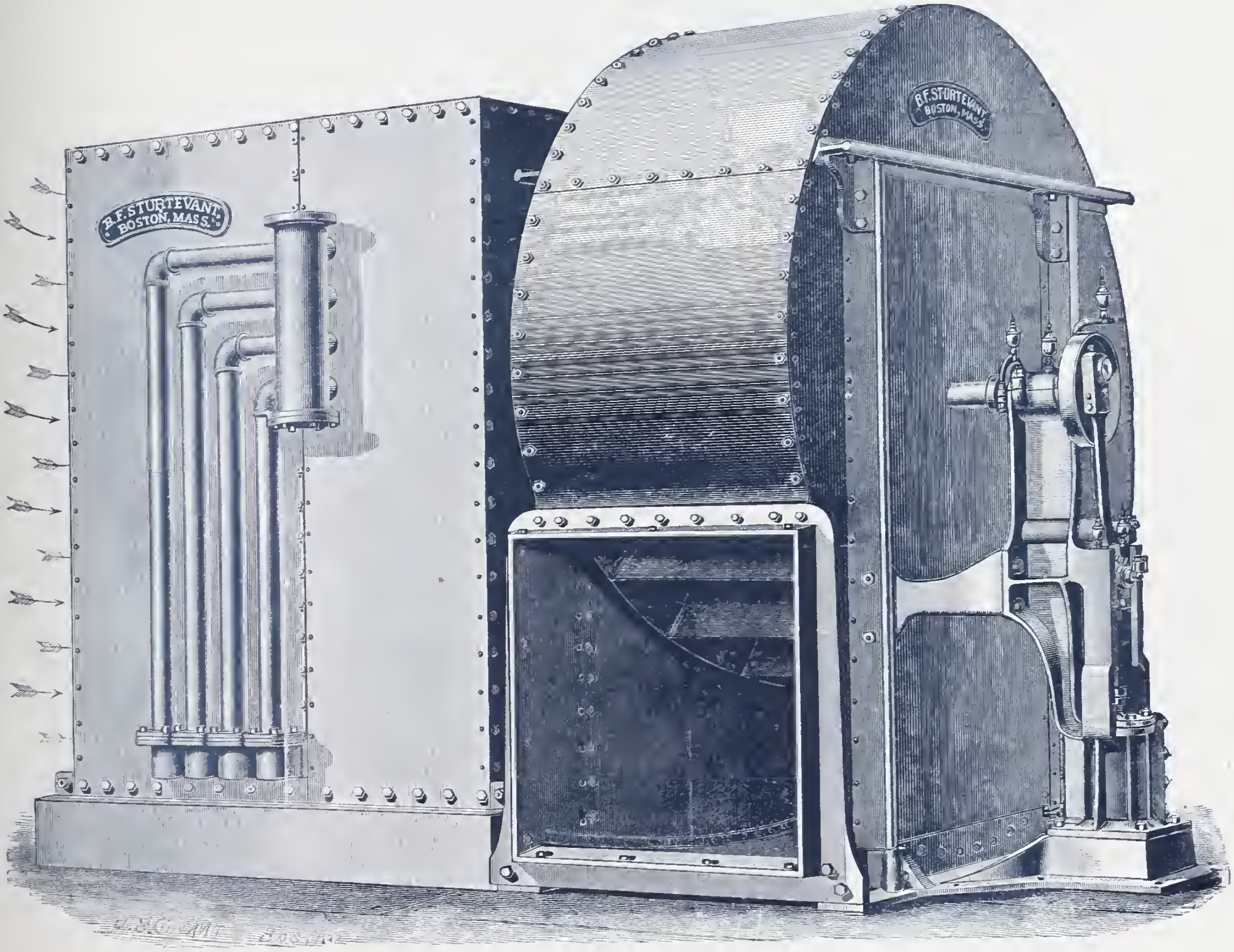


Fig. 23. Standard Steam Hot Blast Apparatus.

The outer end of the heater may be left open, and air taken from the apartment in which the apparatus stands, or a hood may be attached and fresh air drawn from any convenient point. Direct connection is made between the heater and the fan itself. The fan may be made either hand, in various sizes, discharging air in any direction, and the heater of any desirable size or shape. The capacities of the various sizes of this and the preceding style, vary from 5,000 to 100,000 cubic feet per minute.

Steam Hot Blast Apparatus.—Largest Sizes. The largest plants are fitted up in a manner similar to that represented in Fig. 24. The heaters in these large apparatuses are often divided into three separate heaters, of several sections each, and so placed as to form three sides of a hollow square, of which the fan forms the fourth side.

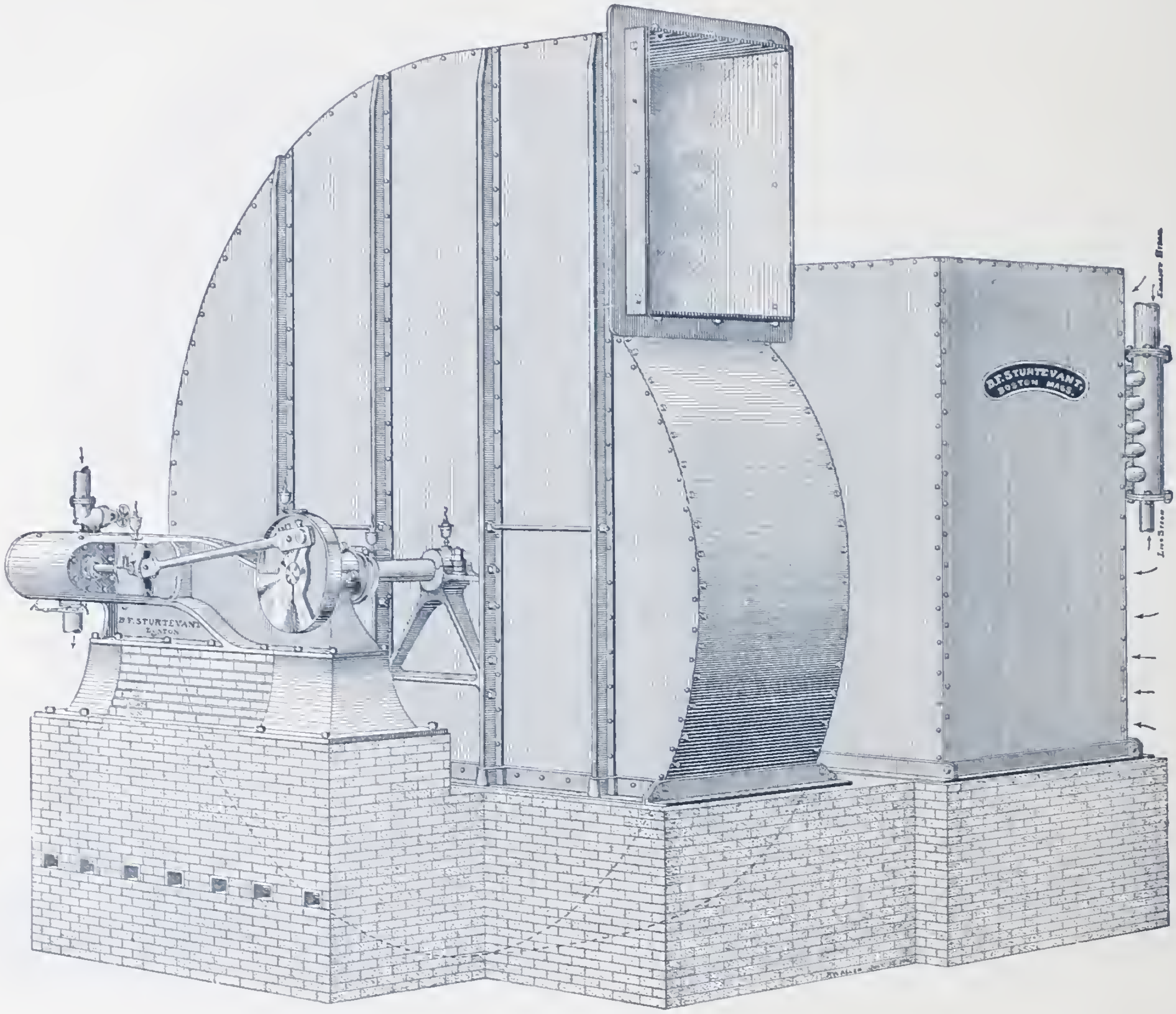


Fig. 24. Steam Hot Blast Apparatus.—Largest Sizes.

It will be seen that this arrangement provides a large area for ingress of air through the heater to the fan. The use of the exhaust from the engine, in a portion of the sections, results in a considerable saving in the amount of live steam required. The engines and fans are built either right or left hand, and the fan may be arranged to discharge in any direction. This style of plant seldom has a capacity of less than 75,000, and, ordinarily, of 150,000 cubic feet of air per minute and upwards.

Application of the

Sturtevant System of Hot Air Heating and Ventilation.

THE following illustrations and descriptions are introduced here simply as characteristic types of the application of the Sturtevant System of Hot Air Heating and Ventilation, and as the most fitting testimonials of the efficiency of the system and apparatus introduced by this house. As has already been made evident, no two buildings require exactly the same arrangement, — special modifications being necessary to meet special conditions. The different types have been selected with care, as illustrating, to as great an extent as possible, the variations in the requirements and the best means of meeting them in buildings differing widely in construction and uses. Of course, it is not to be understood that these are the only arrangements of this system that could have been adopted in the different instances, but, under the conditions here given, they appear to be the best. If ever deemed advisable, the exhaust method can be as effectually carried out by the Sturtevant apparatus as the plenum method.

One-Story Buildings.

THE simplest of all structures requiring ventilation and heating are one-story buildings, such as mills, shops and exhibition buildings. No other form of building has so large an amount of wall and roof surface per cubic foot of enclosed space, and consequently, the most efficient system of heating is necessary. In such buildings the principal provision is to be made for the heating, for the occupants are generally separated, and the air supplied for heating will answer all the requirements of ventilation. But it is nevertheless necessary that they should be provided with fresh air, and the adoption of this method of heating insures such supply. One of the greatest difficulties in a building of this style is to heat it rapidly in the morning, after it has cooled during the night. No other system can so completely and rapidly meet this requirement as that here presented. When it is desirable, the engine may be run slowly all night and the building maintained at a moderate temperature. The exhaust from the engine being used in the heater, no expense is entailed for motive power.

The material of construction has much to do with the size of plant required. When the building is of brick, and of average width, it is best to build main ducts into the basement, connecting with upright flues, built into the walls at proper intervals. The air may then be discharged through registers in these flues at any height above the floor. For buildings not thus constructed the distribution of air is generally attained by means of overhead galvanized iron pipes. As most one-story mills are built with a pitch roof or with a monitor, a good opportunity is there offered to place the hot blast apparatus, entirely out of the way, and connecting directly with the distributing pipes. As the air supplied is generally in excess of that required for ventilation, increased economy can be secured by using over again a portion of the previously heated air. This may be done by arranging dampers or doors so that part of the air entering the heater is drawn from out of doors and part, or, if desirable, the whole from the room.

P. C. & St. L. R. W., Columbus, O. Further explanation of the system can best be made by reference to Figs. 25 to 29, inclusive, representing the arrangement of the system designed and constructed by this house for the shops of the above road at Columbus, O. The principle of distribution adopted is practically the same in each of the buildings which are scattered over considerable ground, rendering necessary a separate apparatus for each. The Hot Blast Apparatus has, in each instance, been placed in what, under the circumstances, was the most convenient position, which in three cases was above the line of shafting, belting and pulleys, and as near the roof as practicable. In the paint and erecting shops a separate apartment was provided. In no case does the apparatus occupy valuable floor space within the shops.

The overhead system of hot air piping was adopted, and the shops being of moderate width, the pipes were carried close to the wall, with the exception of the paint shop where additional distribution was secured by central pipes. Branch outlets were taken from the main at convenient distances, and the air is by them brought down near the floor and close to the walls: The slight impulse of the heated air carries it to the floor line, whence by the natural circulation set up by the cold outer walls, it takes a course toward the centre of the building and finally rises toward the roof. In such a building the air will generally find ready enough exit from windows and doors and through various crevices.

It will be noted that a closed current is usually made by the distributing pipes, so that an equality of pressure and distribution is kept up, any lack of air from one direction being made up by a supply from the opposite direction. Economy of pipe is secured, together with more uniform distribution, by reducing the sizes of the pipes as the branches are taken out from them.

The entire system is giving perfect satisfaction, and supplies a need which has long been felt. It has proved itself economical of space, of material, and of steam, and thoroughly efficient at all times. For round-houses, repair shops, large erecting shops, and railroad buildings generally it is unequalled, and is being rapidly and extensively introduced by the leading and progressive railroad corporations throughout the country.

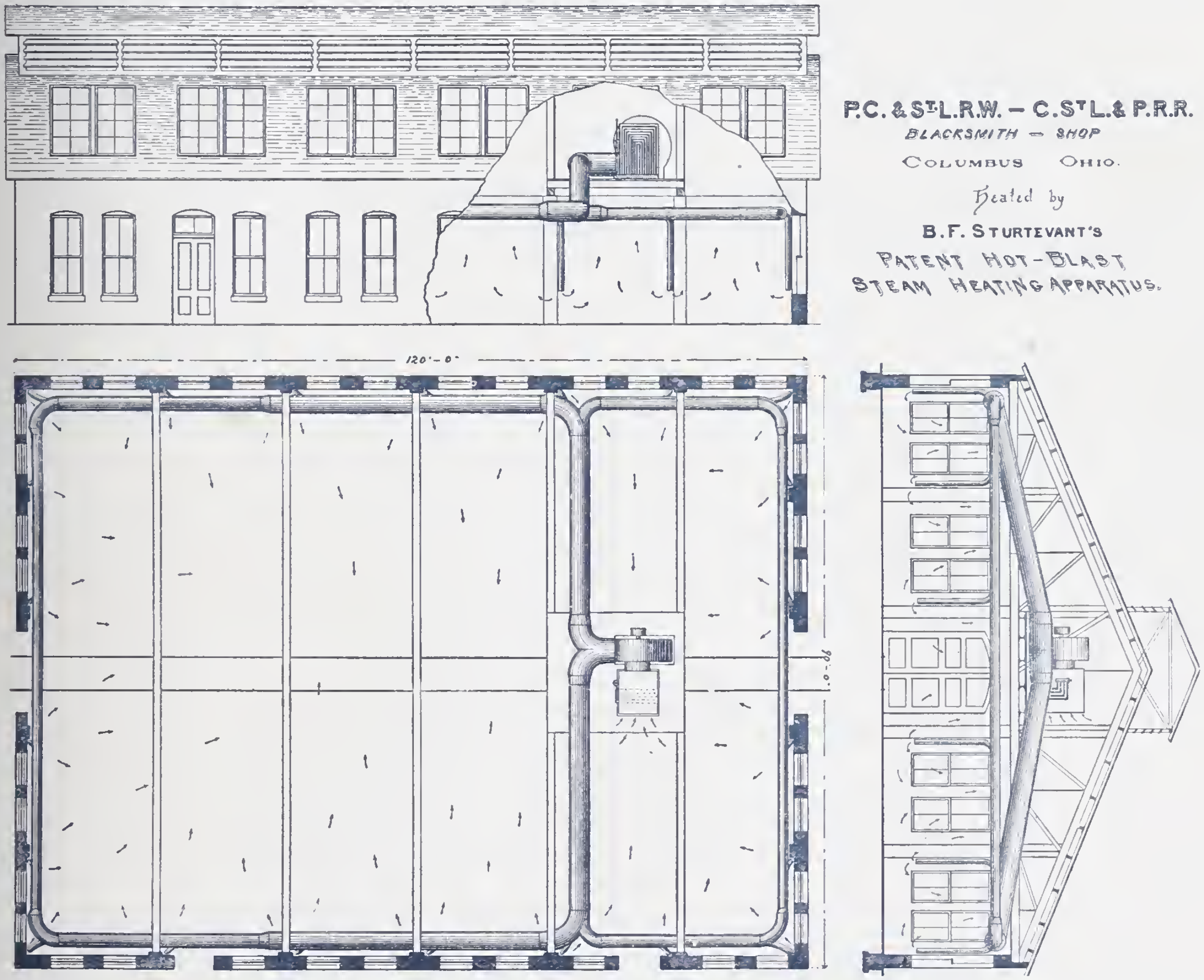


Fig. 25. P. C. & St. L. R. W. Blacksmith Shop, Columbus, O.

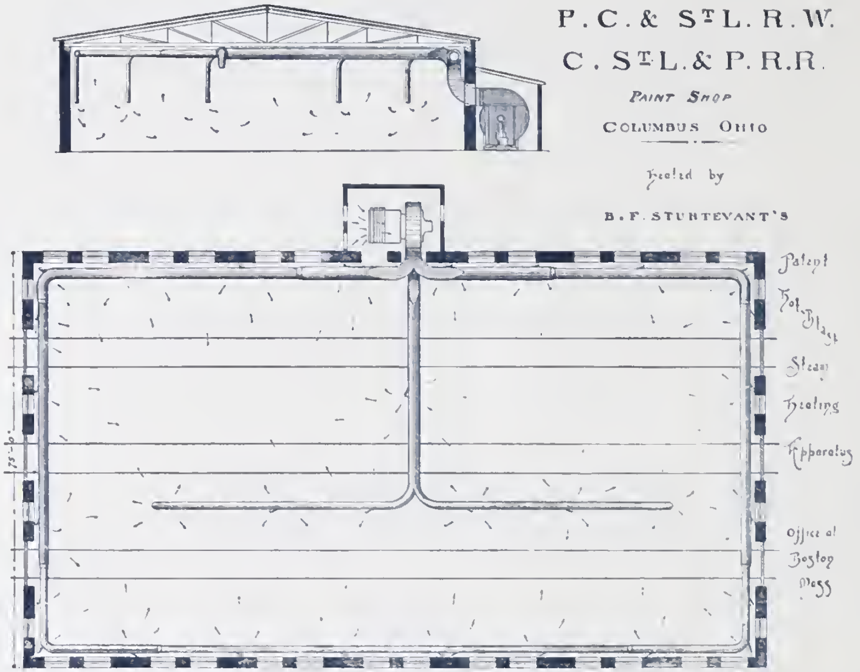


Fig. 26. P. C. & St. L. R. W. Paint Shop, Columbus, O.

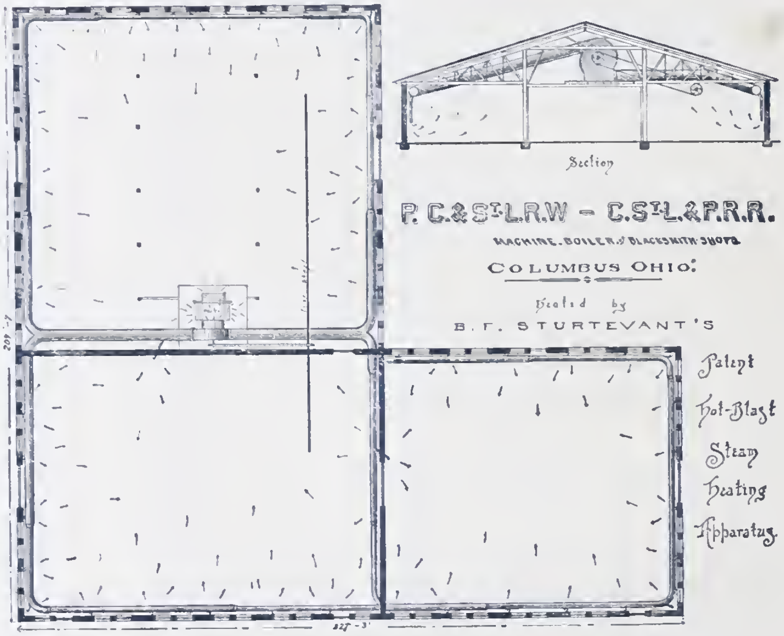


Fig. 27. P. C. & St. L. R. W. Machine, Boiler and Blacksmith Shops, Columbus, O.

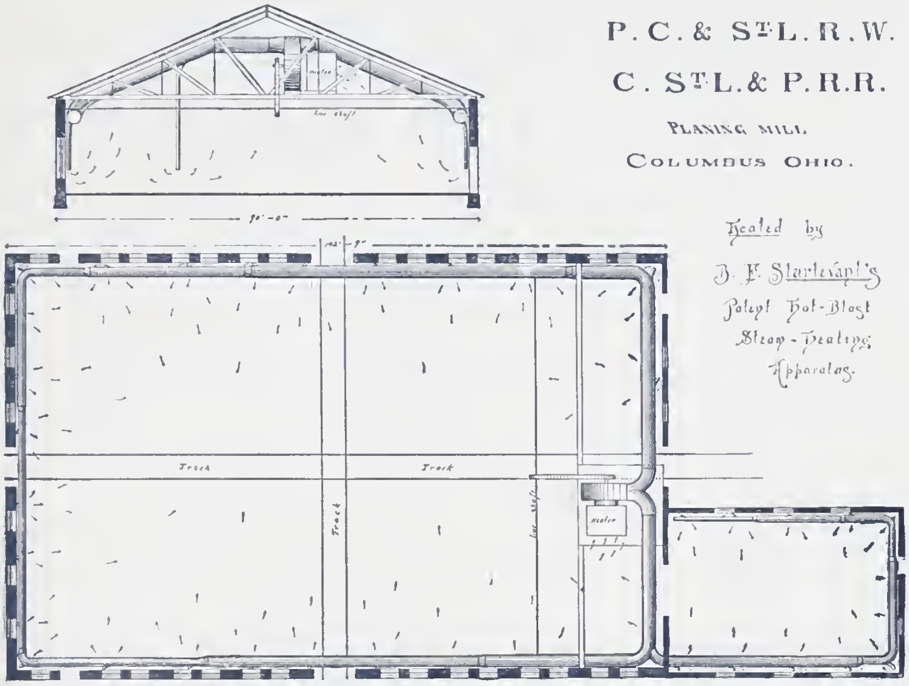


Fig. 28. P. C. & St. L. R. W. Planing Mill, Columbus, O.

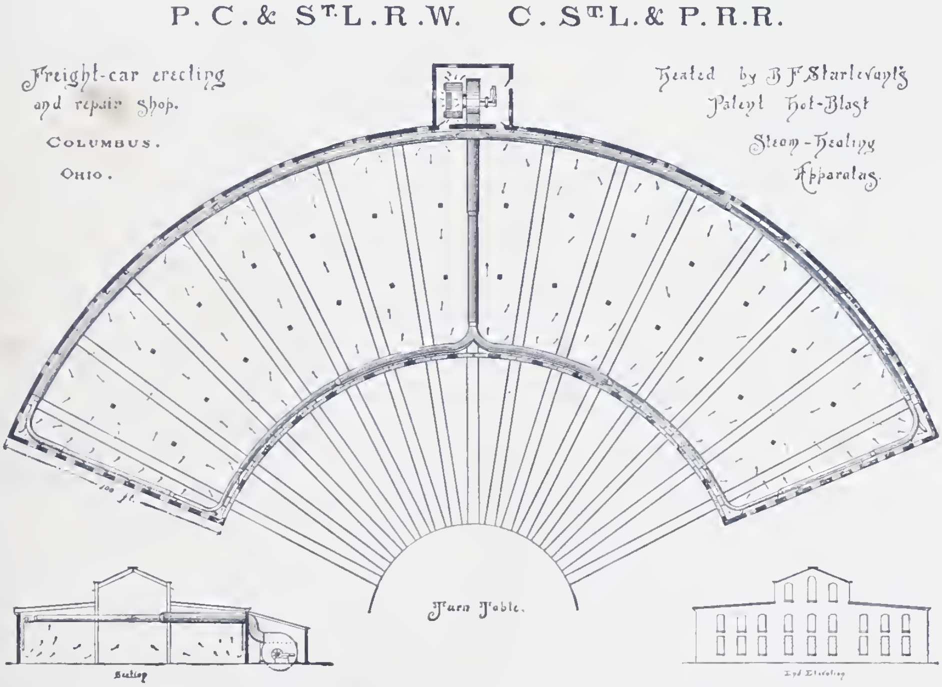

P. C. & St. L. R. W. C. St. L. & P. R. R.
Freight-car erecting and repair shop.
COLUMBUS.
OHIO.
Heated by B F Sturtevant's
Patent Hot-Blast
Steam-Heating
Apparatus.
100 ft.
Turn Table.
Section
End Elevation

Fig. 29. P. C. & St. L. R. W. Freight Car Erecting and Repair Shop, Columbus, O.

Buildings of more than One Story.

As the number of stories and extension of buildings is increased, the Sturtevant Steam Hot Blast Apparatus finds new means of application. In the simplest design, as arranged by B. F. Sturtevant, for a comparatively narrow and moderate sized mill already constructed, the apparatus is placed in the basement near one end of the building. From it the heated air is conveyed throughout the basement by a horizontal pipe suspended beneath the first floor, and thence distributed to the different stories by stand pipes extending to the upper floor. Properly shaped and proportioned outlets in these stand pipes near the ceiling on each floor suffice to distribute the air through the various rooms. Branch pipes can be readily taken out for heating independent rooms where such exist.

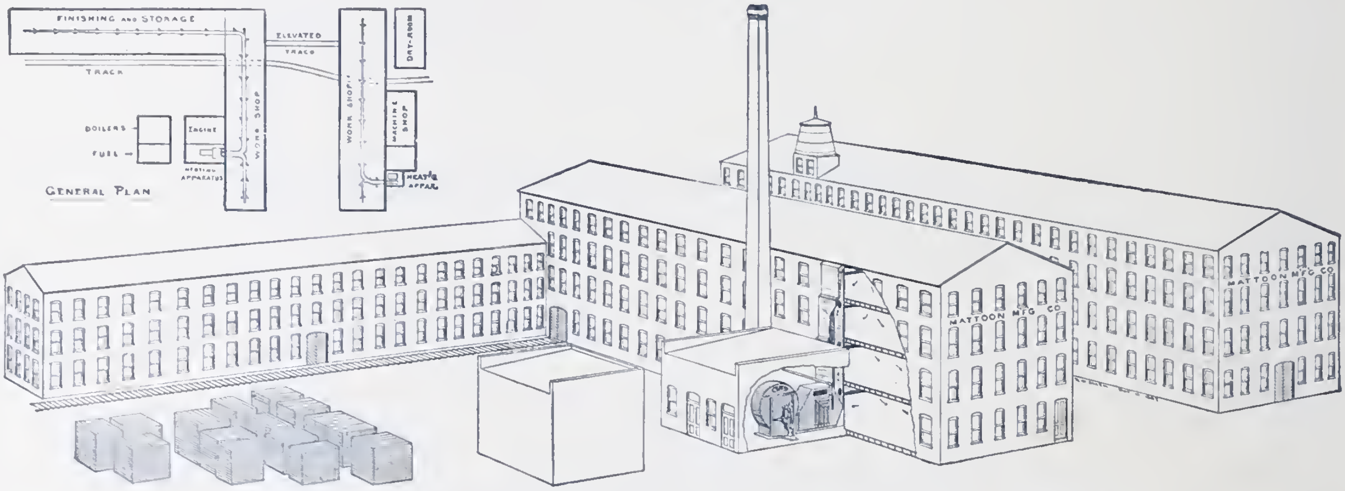


Fig. 30. Plant of the Mattoon Mfg. Co., Sheboygan, Wis.

Mattoon Mfg. Co., Sheboygan, Wis. The case presented by the plan and perspective views of the plant of the Mattoon Mfg. Co., shown in Fig. 30, is slightly more complex, the buildings being narrow and of considerable longitudinal extent. The entire steam heating and ventilating plant was designed and furnished by this house. The two mills in this instance were so distant and distinct that a separate apparatus was deemed best for each. The heated air is conducted directly from the heater to the different floors by a flue built on to the outside of the mill as shown in the perspective view. Thence the air is readily distributed by the pipes running centrally throughout the entire length of each floor. This arrangement results in the greatest economy in piping, the discharge outlets being simple elbows inserted in the main pipe, the latter being gradually reduced in diameter to compensate for these openings. If the mill were wider a pipe might be run upon each side of the room, near the walls.

It will readily be seen how much more easily applied is such a system than any other. The pipes are entirely out of the way, and require no skilled labor in the general erection. The fan and heater are delivered at the works in such a condition as to require but a few hours work in setting up. Compare this with the expense of fitting up a complete direct steam heating plant. In the first place there is the excessive outlay for pipe, then the cost of handling, cutting and threading, the necessity of skilled labor in piping, the necessity for substantial support, the care required to secure perfect drainage and the cost of the supply and drip pipes.

Model Arrangement of the Sturtevant System for Mill Buildings.

Failure to provide proper flues in the walls of a building necessitates the application of the system in the manner illustrated in the preceding cuts. But when the system is decided upon before the erection of the building (as it always should be) convenience and economy will be secured by adopting the arrangement shown in Fig. 31, which represents the plan, transverse and longitudinal sections, of a brick mill building of the ordinary type. A bottom horizontal steam fan is employed, the discharge being beneath the level of the floor. The engine is a direct connected, horizontal engine, and its exhaust is used in the heater, which is made up of the usual sections. By proper partitions or passages fresh air may be taken from one or more of the windows nearest the heater, or from the basement itself, when so desired. The space occupied by the entire apparatus is small, and its location may be changed materially to suit local conditions without affecting the efficiency of the system.

Passing through the heater the air is forced from the mouth of the fan into the dividing ducts which extend beneath the floor entirely around the building. A closed circulation is thus secured so that there is an equable distribution of the heated air. Upright flues are built into the walls between the windows; so far as possible, the greatest thickness of brick being upon the outside. Each of these flues connect at the bottom with the main duct, at which point a regulating damper may be placed if desired. No flue is employed to deliver air to more than one outlet, and these outlets are so arranged as to allow of equal spacing and distribution upon each floor. Better control is always obtained by thus individualizing the flues.

The heated air is finally discharged into the various rooms through adjustable registers in the walls near the ceiling. For some classes of work the registers may be placed nearer the floor; but in cotton, woolen, and similar mills the best results are secured by placing them as here shown. They are then entirely out of the way, and will not be used for a waste-basket or cuspidor. As a rule the air will find ready enough exit through cracks and crevices and open windows, and eduction flues will be unnecessary.

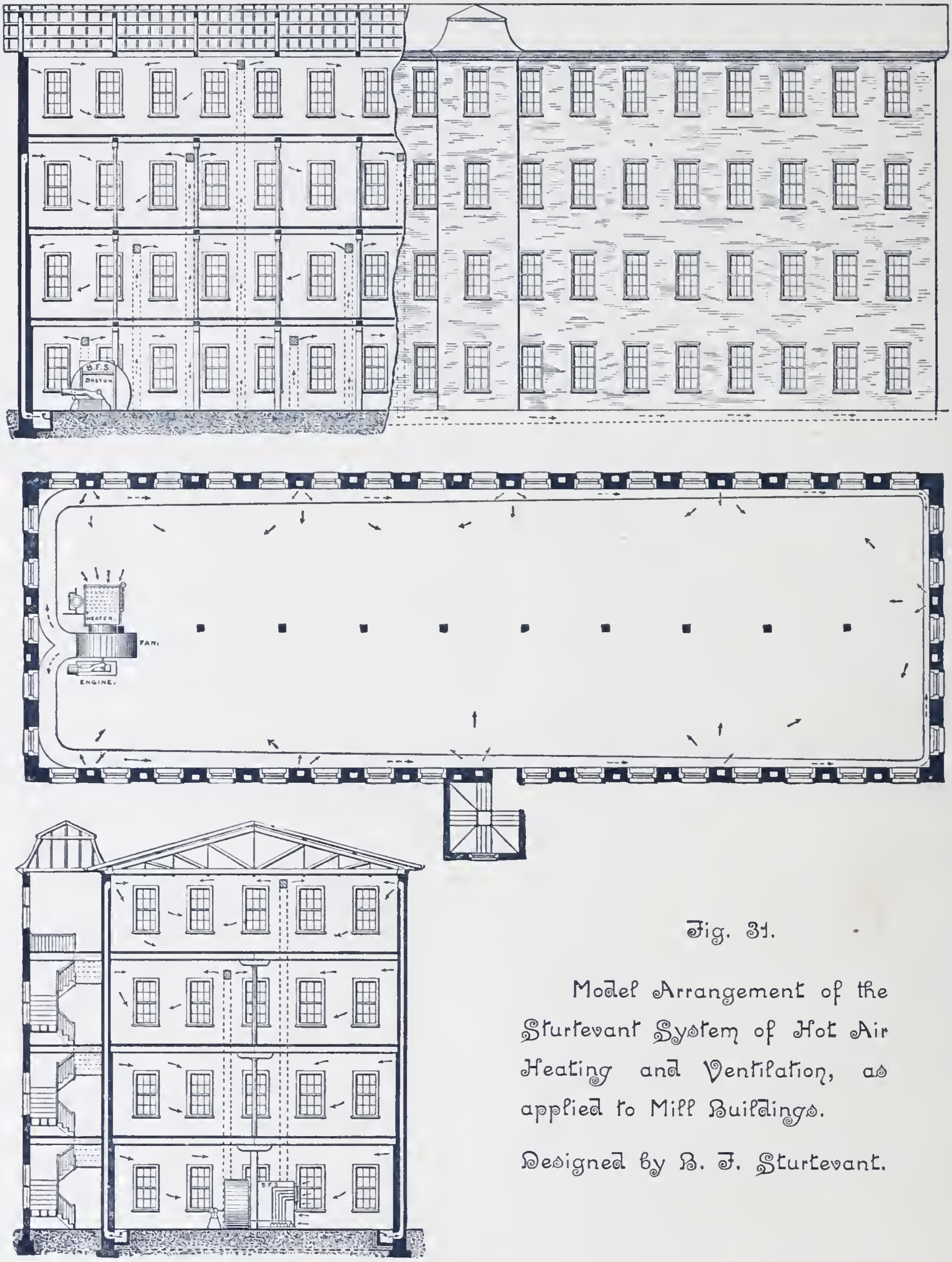


Fig. 31.

Model Arrangement of the Sturtevant System of Hot Air Heating and Ventilation, as applied to Mill Buildings.

Designed by B. F. Sturtevant.

Electricity in Mills. This system has a very important advantage over all others, when applied to cotton, linen, woolen, silk, and jute mills, bleacheries, and the like. The presence of frictional electricity, generated by the motion of belts, pulleys, and running stock and machinery, is a source not only of annoyance but of positive loss to mill owners. In carding and spinning particularly, this electricity has the effect of causing, without a moment's warning, a change of several numbers in the yarn and as much as three per cent. in the weight, weakening the yarn and causing it to snap and break; while the quality and width of woven goods is noticeably affected. Futile attempts have been made to conduct away this troublesome electricity, but all parts of a machine cannot be properly connected for the purpose, and a resulting residue of electricity is sure to make itself known. It is well understood that dry air is a poor, while moist air is a good conductor of electricity.

The entire matter of "Troublesome Electricity in Cotton and Woolen Mills" has been carefully investigated by Mr. Harvey S. Chase, S. B., and the results were presented by him in a graduating thesis at the Massachusetts Institute of Technology. The following brief quotations from this paper will make the matter clear.

"On moist days, by atmospheric conduction, the electricity escapes as fast as produced, while on dry days it is insulated in belt, machine and stock and cannot escape into the air. That moisture plays a very important part in electrical troubles has been noted by all intelligent mill men, and various attempts have been made to imitate the action of the moist atmosphere by admitting water to the mill rooms on dry days. In all places which I have found supplied with a moistening apparatus, the benefit was said to be immediate and considerable, both in decrease in electricity and in other particulars. The effect which moisture in the air has upon electrification in the rooms appears to be dependent upon the percentage of moisture present to that which would saturate the air at the temperature which it has, or in other words, it is dependent upon the relative humidity in the mill rooms. The amount of moisture which the air will absorb depends upon its temperature, and this amount increases rapidly with increase of temperature. With the relative humidity above a certain per cent., no trouble is experienced; as this per cent. decreases, the electricity makes its appearance and grows more and more annoying. The admission of steam will usually increase the humidity, but in cases which have come under my observation, more heat than moisture was received into the room from the steam, and the relative humidity fell, the steam here doing injury instead of benefit, and this is a matter to be guarded against in the use of this method of moistening.

"A careful consideration of these statements will satisfactorily prove, I think, that the whole question of escaping from electrical trouble will be found in the matter of relative humidity. If there is sufficient moisture in the atmosphere, there is no trouble; if there is not sufficient moisture, electricity always appears. The question is resolved into deciding on the best and most satisfactory method of getting the moisture into the mills, and this brings in, as all improvements ultimately do, the consideration of the relative cost of the annoyances and the cure."

As moisture depends upon the currents of air to distribute it, no better means can be found than the Sturtevant Steam Hot Blast Apparatus for obtaining the required results. While doing efficiently its duty as a heating and ventilating medium, the air may be moistened to any desired degree by sprays or evaporating pans in the passages from the heater to the rooms. The exact humidity of the air may be noted by a hygrometer, and regulated to the closest degree. With an average temperature of 70° to 80° in the room, the per cent. of humidity need not exceed 70. This will insure a comfortable atmosphere and will absolutely prevent the presence of any electricity. The mere benefit from this particular source will repay any enterprising owner for introduction, in these days when a saving of a fraction of a cent per yard is of vital importance. But with the additional advantage of an efficient heating and ventilating apparatus, controllable under all conditions, there can be no hesitation in any mind.

Introduction of the Sturtevant System. Enterprising manufacturers are at the present time looking more attentively than ever to the matter of the ventilation of their establishments. They are beginning to see that employees are enabled to do from ten to fifteen per cent. more work in rooms supplied with pure fresh air than they are capable of doing in the close and stifling atmosphere so commonly found in such buildings. Those in charge too often appear to consider their responsibility in the matter at an end when the air in the rooms can be tolerated or endured. But our working people require and desire just as good air while at their work as the proprietor demands in his own home, or in places of amusement.

During the past few years a very extensive business has been built up by this concern in the line of heating and ventilating manufacturing establishments, until, at the present time, many of the large mills and shops throughout the country are fitted with the Sturtevant Hot Blast Apparatus. In all cases the most unqualified approval is given. It gives us pleasure to refer manufacturers and builders to the following parties as a few of those who are now using the apparatus:—

OTIS IRON AND STEEL Co., Cleveland, Ohio.
MORGAN ENGINEERING Co., Alliance, Ohio.
WILLIAM LANG & Co., Brooklyn, N. Y.
EVERETT PIANO Co., BOSTON, MASS.
OXLEY, GIDDINGS & ENOS, New York, N. Y.

Further references, testimonials, and more complete descriptions, with prices, will be furnished to all who desire them.

School Buildings.

As the number of rooms in a building increases, the system becomes more complicated, for each room must be dealt with much as the whole building or floor has been dealt with in the previous cases. The ventilation of school buildings presents at once an illustration of such a condition and a case in which an imperfect solution of the problem endangers the health of hundreds of children and youth. The allowance of space in cubic feet per occupant, is, owing to the close seating, necessarily less than in almost any other edifices, excepting theatres and halls. Scholars in classes have little opportunity for movement beyond their seats, and consequently air and heat must be equally distributed to meet the needs of all. Probably no class of buildings in the United States is so unsatisfactorily ventilated as the public schools. In overcrowded rooms, with inadequate air supply, there is listlessness and inactivity and the seeds of ill health are sown. When any ventilation other than that offered by doors and windows has been provided, it has generally been in the shape of registers connecting with air shafts, and always with the expectation that natural agencies would provide a sufficient supply of the much needed air. When the future welfare of the young of the country is at stake, there should be no stint in any arrangement that will bring up a healthier and sturdier generation.

Massachusetts Institute of Technology, Boston, Mass. The question of heating and ventilation has been wisely and carefully considered in the case of a building recently erected by the Mass. Inst. Tech. at Boston, Mass., which is heated and ventilated by the system described in these pages. A brief description of the requirements and arrangements cannot better be given than by the following extracts from a paper on the subject, by Prof. S. H. Woodbridge, of the Institute, illustrated by Figs. 32, 33 and 34.

"The building to be considered is exposed on all four sides. Its dimensions are 150 feet by 90 feet on the ground-plan, and 75 feet elevation. It contains 40 rooms, whose cubic capacities vary from 3,000 to 60,000 feet, and which are used as lecture and recitation rooms, physical and chemical laboratories, libraries and drawing rooms, apparatus and storage rooms. For recitation rooms and lecture rooms 1,500 cubic feet per hour are allowed to each occupant. For physical laboratories, where the gaseous products of Bunsen flames and electric batteries are likely to act as vitiating agents, 2,000 cubic feet per hour are allowed. For chemical laboratories which are supposed to be supplied with effective hoods for the collection and removal of offensive or dangerous gases and fumes, and also under which any work evolving a considerable quantity of gas is supposed to be done, 3,000 cubic feet, and for the organic chemical laboratory, 4,500 cubic feet, to each

Mass. Institute of Technology, Boston, Mass.

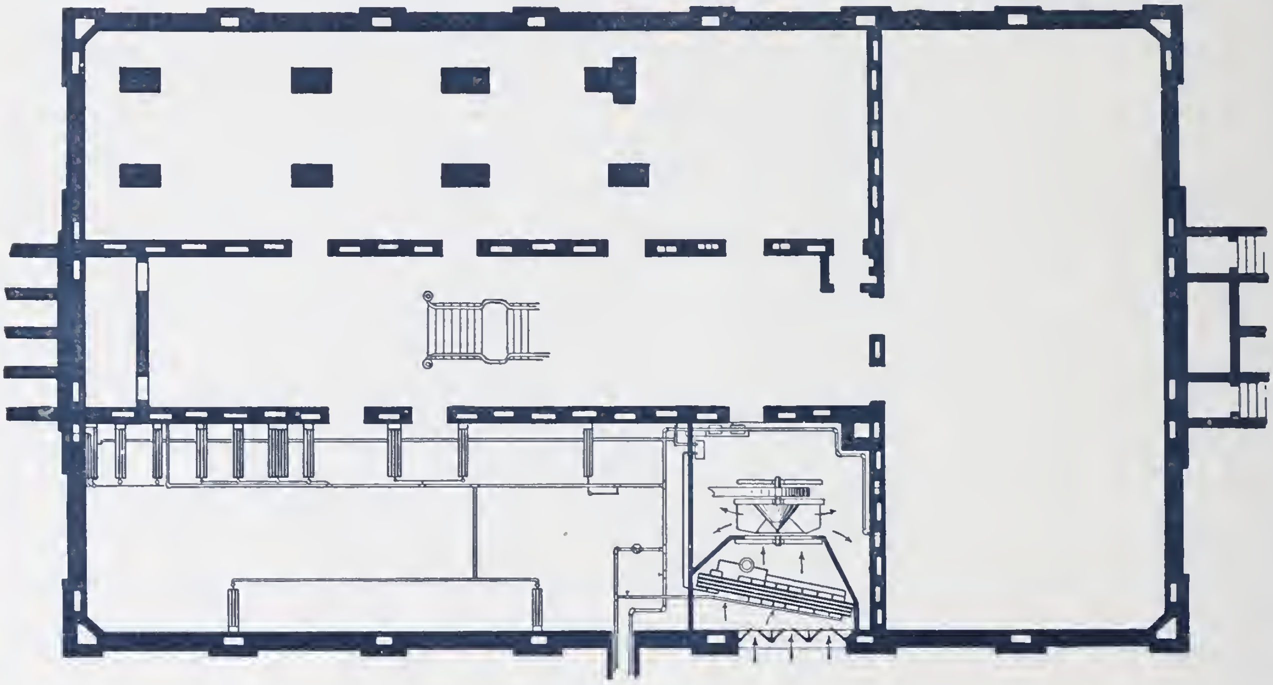


Fig. 32. Plan.

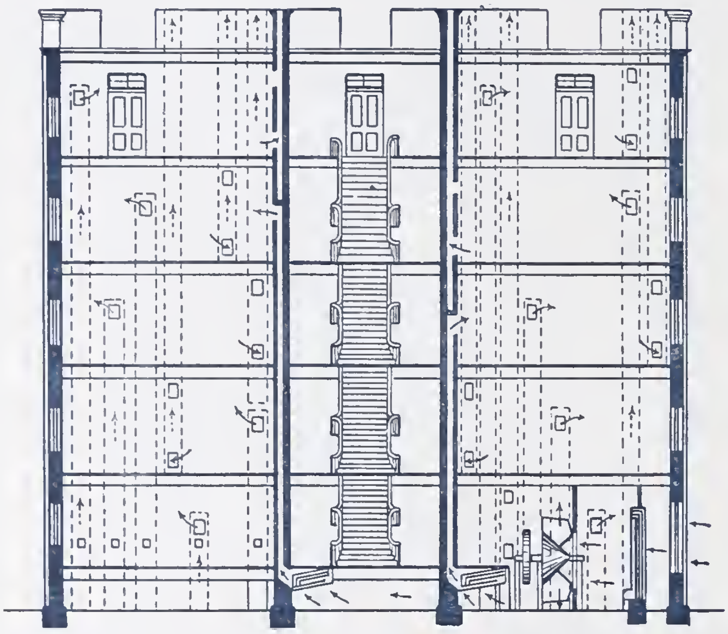


Fig. 33. Cross Section through Fan Room.

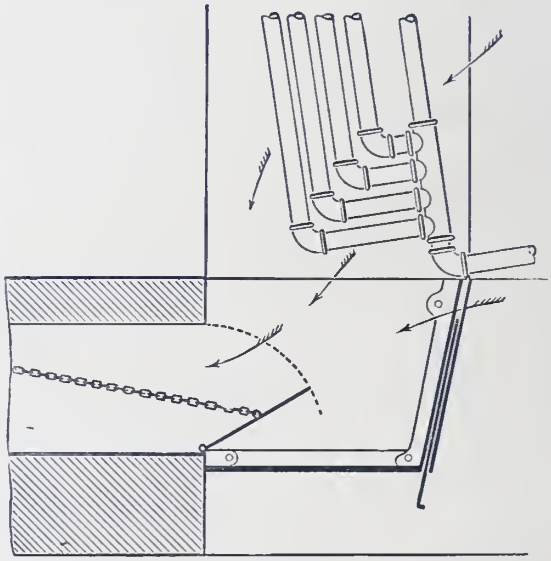


Fig. 34.

Detail, showing Air Dampers in Coil Box.

occupant, per hour. To other rooms of the chemical floor, as the library, balance-room, and volumetric room, 2,000 cubic feet was apportioned to the individual, because of the proximity of chemical laboratories, and the desirability of being able to produce within them an excess of pressure causing an outward air movement. Good ventilation, based on so low an estimate as 1,500 cubic feet per occupant, would not be possible in moist climates, and in the comparatively dry climate of New England, that allowance makes the most efficient and economical use of the supply a necessity.

"The general plan of the walls of the building, which furnished the flue spaces for the air distribution, appears in Fig. 32. The nature of the walls made spacious flues possible. Piers two feet square and five feet from centre, running from the stone foundation to the roof, make up the body of the three interior walls. The face of these piers, with the shell wall connecting them, makes a continuous wall surface. The flues are in general, 3 feet by 1 foot, and are "rough" finished, being smoothed with trowel and whitewash brush only. There are in all 79 flues, including 39 in the outer walls. The distribution of the flues and location and use of the rooms to be supplied and relieved by them is such that all of the outside flues are called into use.

"Among the objections to outer wall flues either as conductors of warm air or outlets for spent air, is their inteference with that movement of air within rooms, which was desired in order to effect their most complete ventilation. To secure such movement, as far as possible, the inlets for air supply were placed in the walls on the warm sides of the rooms, and above the breathing line, and the outlets were placed at the floor upon the same side, and as nearly as possible beneath the inlets. The current of the air from the inlet to the outlet being thus brought into correspondence with the natural rotary movement of the mass of air within a room having a *warm* inner and *cool* outer exposure, the air passed into the room is of such warmth as to remain above the breathing line, until brought down by the chilling effect of the outer wall. Its movement is then across the floor toward the warm side, where it escapes through the outlets near the floor. If the outlet is placed at the outer wall, the tendency is to prevent the cooled and fresh air which falls beneath the breathing-line from traversing the floor before its escape.

"The reasons for adopting this form of inlet and outlet may be briefly stated as—

1st. In so far as the action due to their position goes, it is in accord with the natural air movement within the room, and, therefore, least liable to conflict with the mass movements of air beneath the breathing-line.

2nd. The air enters without passing through the lower strata, and by inductive effect moving increased volumes of that air into recirculation.

3rd. The fresh and warm air *must fall* beneath the breathing-line and *traverse the floor* before it can escape by the outlet.

4th. As free circulation requires large volumes of air at low temperatures, and, as the entering air would be cool to the room's occupants if exposed to its movement, that the currents may enter *above* their heads and be unfelt.

5th. In point of cleanliness it is desirable, since a high wall register is not likely to become a substitute for either dust-pan or cuspidor.

"The schedule shows a larger total inlet-area than outlet. This arrangement is intentional, it being desired to maintain within the building a slight outward pressure to prevent in-drafts through windows and walls, and to secure efficient action of hoods and the exclusion of dust. Each room is virtually an enlargement of the flue or flues connected with it, the air taking a sweep of the room on its passage through the system. The flue which supplies one room with fresh air is generally used for the removal of vitiated air from some room above as may be seen in Fig. 33. The full sized flue is often divided into sections, the different sections connecting with separate floors, they being in reality distinct flues, no single flue supplying air to two rooms. The outlet flues are not so carefully separated as the supply, their division-walls being carried sufficiently high to make it necessary for air to back down twelve or fifteen feet before it can, by reversal of draught, pass from one room into another. The area of inlets to outlet flues is less than the flue area, a condition unfavorable to the production of reversed currents. The outlet flues are full sized at the top of the building, and terminate in the open air without cap or cowl. The inlet (warm-air) flues run down to a common plenum formed by the sub-basement of the building, the piers extending down to the floor of the sub-basement, and the shell walls stopping at the basement floor.

"The plenum extends under the entire building. Its floor, of about 14,000 square feet area, is made of hard cement, laid four inches thick upon the sand and gravel bed composing the made land of the "Back Bay." The floor, is, in its four sections, made by the three inside walls, sloped to central basins so that they may be washed with a hose and drained, The plenum has at one place about 700 square feet of the flooring above it removed, and the corresponding room space above is walled in, making it a part of the plenum. Into this space the outdoor air passes through large windows, and by the fan's action the plenum becomes the reservoir of slightly compressed air, with the flues for its vent pipes.

"The fan used is a modification of Sturtevant's type of ventilating fan. It is twelve feet in diameter and four feet in depth. Its spider carries twelve arms, and at the extremity of each of the arms is a curved and wing-shaped float, forty inches broad at the base and twenty at the front. The arms are bolted to a circular plate forming the fan's back, and to this plate is bolted a cone with its apex toward the fan's mouth. At the front the floats are tied by an annular plate bolted to them and the system is further stiffened by braces between the front extremity of the floats and the arm next following. The diameter of the fan mouth is nine feet, a compromise between the ten feet asked for and the maker's customary eight. The fan is unhoused, and the air passes through its open periphery, the cone facilitating the change in the direction of the air. At ninety revolutions, and with an indicated horse power of fifteen, the fan is capable of moving against the resistance of the flues, and without the assistance of heat, 85,000 cubic feet of air per minute, the pressure in plenum being something like one eighth of an inch water column.

"For the control of air movement through the distributing flues, valves or dampers are placed at their junction with the plenum (Fig. 33), an enlarged detail of which is shown in Fig. 34. By the air valve the engineer can regulate the quantity of air delivered to each room, shutting the supply off from rooms when not occupied by classes and directing it to rooms in use, the flue currents being made to vary with the requirements of the rooms throughout the day. The valves also serve the purpose of effecting an equal distribution against the tendency of strong winds to diminish the velocity of currents through flues delivering air to rooms to the windward side of the building, or increasing it upon the other side. They are also used to overcome the effect of unequal resistance from other causes, such as length of flues. The valve (Fig. 34) is hinged, and is operated by a chain which passes up within the flue to a pulley and through the wall at about four feet from the floor. The same figure shows a sliding damper, also at the base of the flue, the box connecting the steam-coil with the flue having unintentionally a smaller cross-section than the flue itself. In the outlet flues there are two dampers, one at the top to be closed when the flue is not in use, as at night, to prevent the free escape of warm air. The other is at the back of the outlet-registers, and acts as a check-valve in allowing the air to pass freely from the rooms into the flues, and to prevent a movement in the reverse direction. These automatic check-valves are simply flaps of the lightest gossamer rubber cloth, cut into strips about six inches wide, and in length equaling the width of the register face, and so placed that when no current is passing they hang vertically, overlapping each other about half an inch.

"The air is warmed to 60° Fah. immediately after passing through the inlet windows and is further heated as required for the various rooms by means of coils at the base of the flues. The heating surface is in two parts; a main coil at the entrance and the supplementary coils at the flue bottoms. There are several reasons for this division, principal among which is the protection of water and other pipes in the sub-basement from frost; and for the warmth of the basement proper the air in the basement must be warmed to 60° or thereabout. This air cannot be advantageously warmed above 60° as some of the rooms frequently require a flue-temperature, little, if any, above 60°. The supplementary coils are needed, since the various rooms require different flue-temperatures. They are placed in the sub-basement because of compactness and to prevent damage by leakage, but more particularly to place the valve manipulation in the hands of the engineer.

"The main heating coil is made up of eleven sections. Each of the sections is made up of ten sub-sections, so put together that in case of accident to any single pipe, the sub-section to which the damaged pipe belongs may be removed for repairs. The coil contains about 7,500 lineal feet of pipe and the free area for air passage through it is about 120 square feet. The regulation of temperature and steam pressure within the coil is by means of a reducing-valve set at any fixed point less than boiler-pressure, and by shutting off one or more of the coils, or by the 'by-pass' over the coils. The supplementary heaters are of the same general character as the main coil, being made up of pipes widely spaced to allow free air-movement; the heating-surface in each coil depending on the flue-temperature required, which for any room varies inversely as the ratio of its air supply to its capacity. The total length of piping in these coils is about 14,000 feet. The temperature of each of these supplementary coils is controlled by a fractional valve. Humidity is imparted to the air passed through the flues by means of the large and moist concrete sub-basement floor over which it must move before reaching the flues.

"The general results of the system's operation are accepted by those occupying the building as exceptionally good, and the opportunity which its detailed character affords for study and experiment, will, it is hoped, lead to investigations of a fruitful order."

The entire system as here explained, is readily applicable to any similar building in process of erection, and with other arrangements of air-flues, to any building already constructed. No school building should be planned in this enlightened age without adequate provision for heating and ventilation.

Dwelling Houses, Offices, Stores and Prisons. Dwellings and buildings consisting principally of moderate sized offices, may be heated very much as school buildings but the amount of air required for proper ventilation of the various rooms will, obviously, be dependent upon the number of occupants, but they should have full control of the admission of air to their respective rooms. Stores, particularly those devoted to the retail trade, most urgently require a thorough system of supply of cool air in summer and warm air in winter. They can most readily be supplied by the Sturtevant system, the registers being placed beneath the counters, in the walls and other available places.

Prisons, reformatories and the like are similar in some respects to school buildings, but the cells as a rule are directly connected, through the grated doors, with the corridors. Movements of heated air, which warm the corridors and pass into and render the cells comfortable, are preferable to placing any heating apparatus in the cells themselves. The Sturtevant system and apparatus has been applied in a number of the State penitentiaries of the country, with marked success.

Hospitals and Asylums.

HOSPITALS and asylums are similar in many respects to school buildings, but differ in that the rooms are generally large and continuously occupied. They contain less occupants for a given space, but for each of these occupants a larger supply of air is required. As a class, hospitals and asylums have received more than ordinary attention by architects as regards their ventilation, and to a greater extent than other structures they are provided with the necessary flues in the walls. Perfect ventilation is imperative, and the effect of a lack of it has been clearly shown by statements in the opening pages. Particularly, in hospitals intended for the reception of contagious diseases, an excess of air must be provided to dilute to the greatest extent possible, the poisoned air emanating from the patients.

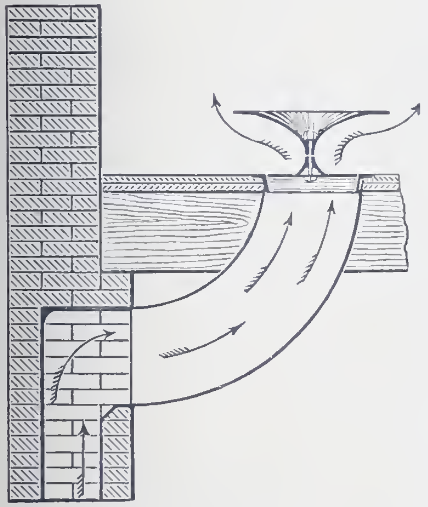


Fig. 35.

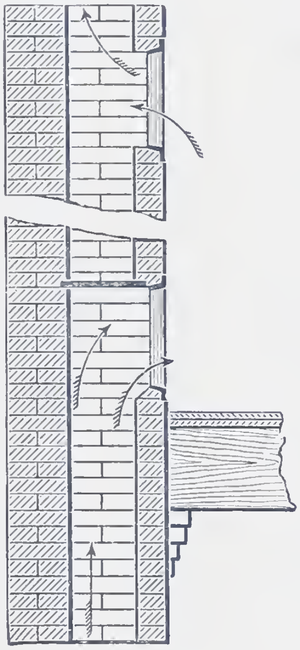


Fig. 36.

The most natural, and practically the most successful place for admitting air is found to be at, or near the floor, provision being made for its removal through exhaust-flues in the walls. As the beds in the different wards generally have permanent positions assigned them, the inlet registers can most conveniently be placed beneath them. The air then passes up upon either side of the bed, without any appreciable velocity, and carries with it whatever germs and odors may be present. In wide wards further provision may be made for heating by registers placed near the middle of the room. In offices, operating rooms, etc., the position of inlets and outlets must be decided upon with reference to the construction and location of the rooms. The arrangement of flues for the introduction of air near the floor, and removal near the ceiling, where the flues are properly built into the walls, is shown by Figs. 35 and 36.

When the air is to be admitted beneath the beds, it may be conducted from a supply flue in the wall through a metallic pipe to a register in the floor, as represented in Fig. 35. If the ascent of the heated air against the bottom of the bed is objectionable, an inverted cone may be attached to the centre of the register, as shown. This arrangement will insure a complete and wide distribution of the air. In other cases it may be advisable to admit the air directly from the flue through a register in the wall near the floor, in which case the design in Fig. 36 will be found advantageous. A continuation of the same flue may be employed either on the same or a higher floor, for the purpose of removing the foul air, as shown in the upper portion of the same figure.

Among the many hospitals heated and ventilated upon the Sturtevant system and by the Sturtevant apparatus, are the

Northern Hospital for the Insane, Elgin, Ill.
Willard Asylum for the Insane, Willard, N. Y.
Murdock's Free Hospital, Boston, Mass.

Legislative Halls.

HALLS of audience such as churches, theatres, legislative assembly rooms and schools, above all buildings in this country, require special ventilation. They vary in time of occupancy from one or two hours once a week, to many hours six and even seven days in the week. This calls for a very quick acting system which shall work effectually for a comparatively short time, but nevertheless, one that may be relied upon for continued service under special circumstances. Such buildings are usually so closely filled with people, often retaining their out-door apparel, that the requirements for ventilation reach the maximum. Nothing but mechanical means can attain success in this direction. Slight attention has, in the past, been paid to the ventilation of churches in connection with their heating. But notable advance has been made in this line during the past few years.

House of Representatives, Washington, D. C. Legislative halls having audiences varying so materially in number and time of occupancy, must emphatically be fitted with a perfect system. The Hall of the National House of Representatives of this country presented many obstacles to successful ventilation. Two sectional views of the same are presented in the accompanying Figs. 37 and 38. The Hall is surrounded by corridors and committee rooms so that all its walls are internal walls and it is lighted entirely from overhead by a skylight, which extends over the greater part of the Hall. Beneath is a basement story, 20 feet high, and beneath this again is the cellar or crypt in which the ventilating apparatus is placed. The fresh air is conducted to the ventilating apparatus through a tunnel from a terrace at a distance of about 200 feet from the building. The Sturtevant fan has been adopted, and several are in use, for different purposes in connection with the ventilating apparatus. The illustrations give the general manner of distribution of air to the Hall, and the method of removal from it; entering and passing out as indicated by the arrows. The section through air ducts and heat-

South Wing U. S. Capitol, Washington, D. C.

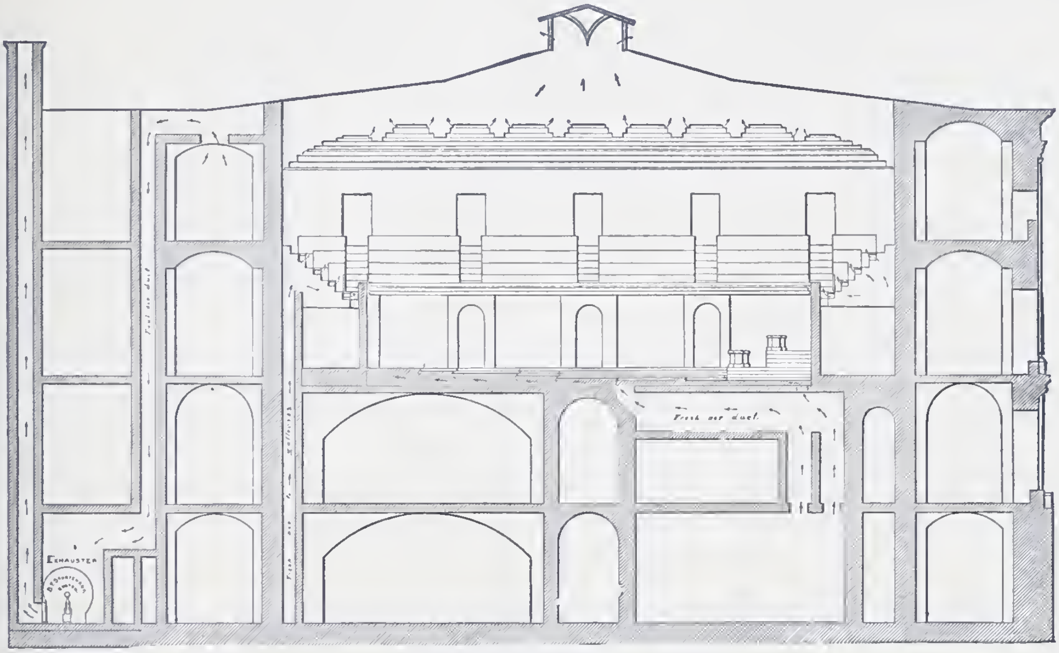


Fig. 37. Transverse Section.

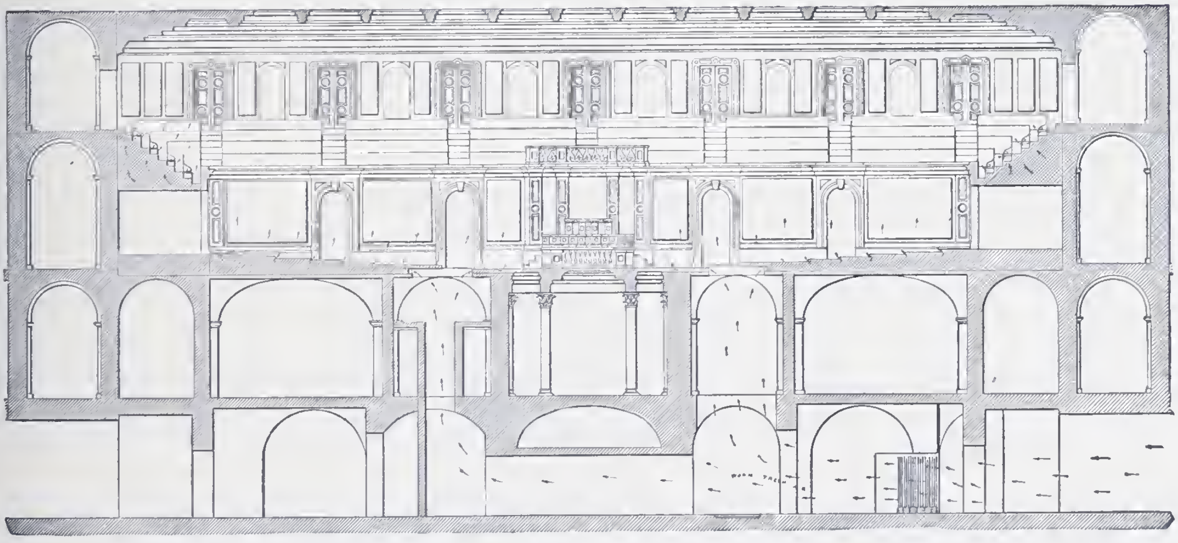


Fig. 38. Section through Air Ducts and Heating Apparatus.

ing apparatus (Fig. 38), shows most clearly the currents in the cellar; the fan which impels this air is not shown, being situated at some little distance from the heating apparatus. In Fig. 37, however, one of the exhaust-fans is represented as it is arranged to draw air from the corridors. This arrangement results in a plenum effect in the main hall, making all the leakage outward.

The air in the main hall is admitted beneath the seats and discharged at the top of the room into the space connecting with the ventilators at the top. The efficiency of this system, as here applied, is made manifest by the following extract from the report in 1878, of a committe appointed to investigate and report upon the system. "The present system of heating and ventilation of the House of Representatives is based upon correct principles, and should not be changed for any of the so-called systems of natural, or downward, or lateral ventilation."

Similar apparatus has been applied by this house to many public buildings throughout this country and Canada, prominent among which are the Houses of Parliament, at Ottawa, Canada; the State House and City Hall, at Boston, Mass., and the Indiana State Capital, Indianapolis, Ind.

Theatres.

THEATRES, of all halls of audience, require the greatest care and the most extended experience in the designing of a system of ventilation and heating. They consist of three different parts; the entire body of the house or auditorium; the stage and side rooms; and the lobbies, corridors, stairways and offices. But the distinction and separation between these different parts changes at different times during a performance. The simple rising of the curtain, throws into one, the two previously distinct apartments,—the auditorium and the stage. So too, when all the doors are opened into the corridors, the distinction between the auditorium and corridors is materially lessened. It will be readily seen that arrangements based upon the separation of these various apartments will be rendered entirely ineffective when it is possible to so suddenly and radically change these conditions.

As a rule, theatres are located in cities with buildings abutting on two or more sides and allowing of no direct connection, by windows, with the external air. In fact, no means but artificial means can ever produce satisfactory results in such places, and furthermore, only the system of forced circulation has complete control of all conditions. Generally speaking, it is advisable to create a slight excess of pressure in the auditorium in order that all openings shall allow for the discharge, rather than for the ingress of air. This condition will cause the curtain to swell slightly toward the stage.

The close seating of the occupants produces such a large amount of animal heat, that, considering a theatre once filled and thoroughly warmed, it usually becomes not so much a question of warming as of cooling to produce comfort. Occupied as they are for a number of hours, a continuous working system must be provided, and no reliance placed in one that puts the atmosphere in good condition at the beginning of a performance, but fails to maintain that good condition. Architects have, during late years, devoted a great deal of attention to this matter with marked improvement in the condition of newly constructed theatres. Many failures have, however, resulted from inexperience or a thought that any one can design an efficient system. It is much safer to call in the services of engineers who have made a study of such work and are fully qualified to carry it out.

Metropolitan Opera House, New York. One of the best examples of the application of the system set forth in these pages, with which this house has been connected is now in successful operation in the Metropolitan Opera House, New York City. Great care was exercised in all the details with a most marked improvement over the condition of ordinary theatres. A very clear and concise description of the entire arrangement appeared in the Sanitary Engineer shortly after its introduction, and from it we quote the following extracts, illustrated by Figs. 39 to 43.

"The principle involved is 'plenum ventilation,' the object being to have an excess of air entering the building to that which is leaving it by the regularly provided foul-air outlets. The result of this is to have a pressure within the building, slightly in excess of that of the air without the walls, so as to insure an outward current through crevices of doors or windows, or through accidental openings. To accomplish this in a practical manner, a blowing engine must be used, and the supply of air must be almost unlimited. To this end, the shaft (at the left of the stage on the ground plan), 7 ft. by 10 ft. 6 in. (73.5 square ft.) was provided in connection with the fan. Air is taken in at a height of 75 ft. from the ground, and 60 ft. below the top of the boiler chimney, and as remote therefrom as possible, being on the North or Fortieth Street side of the house. After the air has been drawn down through this shaft it enters a settling chamber, 48 ft. by 20 ft., with a height of 10 ft.; thence it is drawn through the heating coils *C*, or passed around through the swinging doors, as shown, to the fan. From this point onward, there is now a condition of *plenum*, and all of the building within the walls, *A A A* and the proscenium walls is supposed to have a pressure slightly in excess of the outside atmosphere. From the fan, the general course of the air is through the main air duct, between the walls *A* and *B* in the basement in the direction of the arrows, but all the basement within the walls *A A* is subject to the same pressure. From the basement room, imme-

Further Application of the Sturtevant Apparatus.

Steam and Sailing Vessels. While efforts are continually being made by all the great Steamship Companies, notably those that compete for the travel between Europe and America, to improve their ships, reduce their time of passage, and to make comfortable the passengers, no expense being spared in decorations and luxurious fittings of the saloons and rooms which are the temporary home of travellers, it seems strange indeed, that the simplest and most vital condition of health has been quite neglected. There is no doubt that the greatest defect in a modern steamship is the failure to provide an adequate and constant supply of pure air, at all times and in all those parts of the ship that are occupied by passengers and crew. Most of the discomfort of an ocean voyage, including seasickness, arises from the bad air which every one is obliged to breathe when below decks with the air ports closed, especially in rough weather. The remedy is simple, effectual and inexpensive. The ready servant, the fan, used either as a blower or as an exhauster, is here employed, and by it, the thorough ventilation of every part of the ship can be secured. The staterooms and saloons can be given the freshness of the outer air instead of the stuffy and oppressive atmosphere that now characterizes them.

The problem is of equal importance in naval vessels, and the course of its inception and successful solution in the American Navy is fast leading the merchant marine to adopt this most benificent improvement.

In March, 1878, the Secretary of the Navy appointed a board of officers "to examine and ascertain the best system of ventilation, by mechanical means or otherwise, by which the ships of the Navy may be more perfectly ventilated than at the present time." This board made an examination of the U. S. S. Richmond and reported:— First, upon the necessity of ventilation, showing "the filthy condition of the atmosphere generally on shipboard, which both men and officers are compelled to breathe; thus inducing disease, impairing health and increasing the mortality." Second, upon the necessity of some mechanical device to keep up the circulation of air, giving reasons why "no system of ventilation can be relied upon which depends for action on induced currents produced by the difference of densities or the difference in the static and dynamic heads of the internal and external air." As a mechanical device for ventilating, it was recommended "that a fan of the most improved type, and one that has been thoroughly tested and found efficient, be adopted and that this fan be fitted to exhaust the air from all parts of the ship by means of suitable pipes leading throughout, and fresh air will find its way through air ports and hatches to replace the air removed." And further they recommended "one exhausting fan to each side of the ship, to draw air from the pipes, and that these fans be fitted with an independent engine for driving."

In the Army and Navy Journal, for 1879, there appeared an article on the ventilation of ships of war, by Chief Engineer J. W. King, U. S. N., from which the following is quoted:—"No exhausting fans, such as are used for the ventilation of buildings, being found applicable to the conditions required on the *Richmond*, it was determined to construct them. Accordingly, after consultation with Mr. B. F. Sturtevant, who has had a large experience in ventilating buildings, a contract was made with him to build two exhausting fans, with engines connected direct. * * * The system of ventilation, as applied to the *Richmond*, is unquestionably correct, and, although the details of the method employed for removing the air are not perfect, a great measure of sanitary reform has been accomplished in the navy, and in time the subject of ventilating ships will be as carefully considered as the supply of water and drainage is considered by engineers of cities. When the apparatus was tested, —the crew being on board,—it worked admirably and almost noiselessly, the purpose for which it was designed being accomplished fully up to what the most sanguine friend of sanitary reform could have hoped for. The air to be exhausted flowed freely to and through the openings in the receiving pipe from all parts of the ship to be ventilated, with facility, as indicated by the currents entering the registers, while fresh air imperceptibly descended to supply that removed, and without objectionable currents. In addition to removing the foul air, it was found to be useful as a means of drying the deck. On the arrival of the ship at Gibraltar, from New York, after being twenty-five days at sea, Chief Engineer Baker writes: 'The exhausting fans work well and are a very great comfort by supplying us with pure air. There is no smell of bilge water and no odor of impure air on the berth deck at night. Moreover, dampness is prevented, the berth deck being rapidly dried after being wet from washing. It may, therefore, be confidently stated, that the *Richmond* is now by far the most completely ventilated ship that ever sailed under the American flag, or, indeed, under any flag. The officers and crew of the ship will enjoy pure air at all times, when in healthy localities, and warm apartments (heated by steam) when in cold weather, comforts unknown to the senior officers of the navy in their cruising days.'"

Two years later, in a pamphlet upon the Ventilation of Ships, appeared the following statement: "The *Richmond* has now been cruising in the Asiatic seas for about two years. The reports from her officers during this time speak in such strong terms of the successful ventilation and as a consequence, the good health of the crew, that the Government has given an order to Mr. B. F. Sturtevant to supply three more ships, viz.: the *Brooklyn*, the *Lancaster* and the *Hartford*, with the same kind of exhausting apparatus; and it is quite certain that no U. S. ship-of-war will hereafter be built without this very necessary apparatus."

This prophecy has been completely fulfilled. Every steam vessel built by the U. S. Navy since that time has been supplied with fans, and *all of them have been furnished by B. F. Sturtevant.* In fact, this has come to be a special balcony, to other flues in the wall *B* on the right and left. Into these flues connect the openings from the hoods over the gas lights in the balcony and gallery, each hood being a register. In the highest part of the gallery ceiling, in the rear, are five registers, under two of which there are clusters of gas brackets, the aggregate area being 20 square feet. In the balcony ceiling there are likewise *four* registers of 15 square feet, under each of which there is a cluster of gas brackets. The foul air from these is likewise carried to the wall *B* in galvanized ducts. In the centre of the dome-shaped ceiling is the main controlling valve to the ventilation. It is circular, 16 feet in diameter, and admits of any adjustment by the rising and lowering of the bell-shaped disc by a winch. By the adjustment of this valve, the pressure within the house may be regulated and the condition of plenum maintained under varying conditions of the speed of the fan made necessary by the climatic changes. All the foul air outlets in front of the proscenium wall open into the space between the ceiling and the roof, and reach the outside atmosphere through the louvred ventilator at the apex of the roof. This ventilator has openings equal to 108 square feet, with louvre boards of peculiar construction and an inner shield to prevent the admission of snow or rain. The stage has separate ventilators at the roof and in the side walls, and is warmed by direct radiation coils on the back wall. By this means a difference of pressure is kept between the house and the stage when the curtain is down; enough to belly the latter slightly toward the stage. The rising of the curtain then allows air to pass from the house to the stage ventilators.

"The method of managing the warmth of the house in cold weather, has been to keep the temperature at about 78° in the day time by slow movements of the air at a temperature of about 80°. The object of this is to warm the walls and all objects somewhat above the temperature required when the building is occupied, so as to prevent radiation or the loss of heat from the bodies or shoulders of people in evening dress, to the walls or surrounding objects. Then, in the evening, when the building is to be occupied, the temperatures in the air ducts are dropped to 70° and the air sent in full volume through the house. The result is, the thermometers show a higher temperature in the auditorium than that at which the air enters through the openings, etc., due, presumably, to heat received from the walls, floors and warm passages. Then, as the evening advances and the effect of the heat from the gas and from the human body increases, the entering air is lowered to 67° in the main duct. With this latter temperature in the duct at 9.30 P. M., the temperature throughout the house ranges from 70° to 73° F., according to location, being coolest in the balcony and gallery.

"On the evening of November 7, 1883, at 9.30 P. M., and after the air in the duct had been lowered to 68°, the temperature at the wire of the parquet circle, a little to the right of the main entrance, was 70°. At the floor of the parquet at the same place it was 70°. Half way round the house, to the left, breast high, it was 74°; in the same position to the right it was 72.° In the first tier, center box, on a chair, it was 73°. In the salon, behind the box, 74°; and for other parts of the house it was: Balcony right, 71°, left, 72°. Air entering through openings, right, 70°, left, 70°. Family circle (gallery), centre, 70°, left, 72°; right, 72°. First tier, lobby, outside wall *A*, 70°. In air duct, last experiment, 11 P. M., dry bulb, 67°, wet bulb, 53°. In the coil chamber, between the coils *C* and the fan, is placed an evaporating pan, to regulate the hygrometric state of the incoming air.

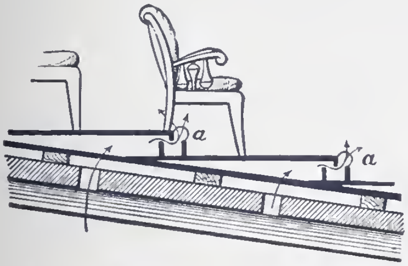


Fig. 42. Parquet Chair.

"Fig. 42 is a detail of the manner of admitting air through the auditorium floor. The arches are of brick, and the whole space between them and the wooden floor is filled with warmed air, which enters through a baffle, *a*, that runs the whole length of the steps. The iron moulding at the edge of the steps is perforated with small holes to admit the air in a spray, and its shape is designed to direct and diverge the jet over 180 degrees of a circle, the object being to admit a large quantity of air imperceptibly.

"Fig. 43 is a section and plan of the private boxes, of which there are 120. The air is carried through the floors from the flues in the wall *A* (as before mentioned), and delivered at the edges of the box balconies, as shown. To each two boxes is arranged a vent flue, as shown in plan. A special corner-register face is arranged in each box, with a septum extending inward, as shown, to intercept light, etc. In each register is fixed a small bell-mouthed funnel, extending a short distance into the flue. Under this funnel is an argand gas burner, the products of combustion of which are drawn into the flue directly and not allowed to escape into the salon. The heat which accompanies the combustion may also be a help to the draught of the flue.

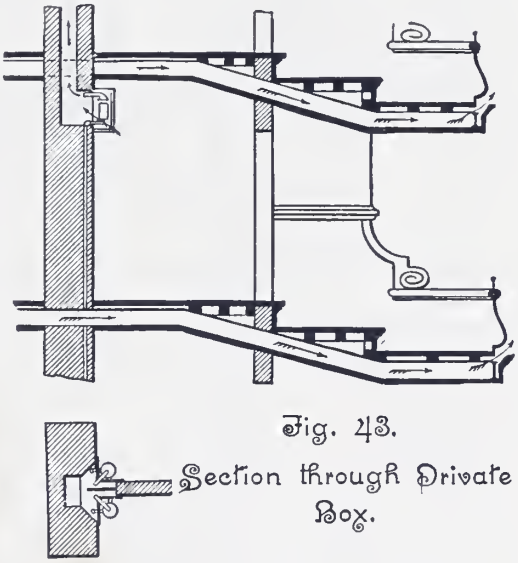


Fig. 43.
Section through Private Box.

"The main fan is 12 ft. 6 in. in diameter by 45 in. in the width of the blades and delivers about 70,000 cubic feet of air per minute when it is running 100 revolutions per minute. The fans used are the 'Sturtevant' make; the main fan is driven indirectly from the engine, the speed of the engine being regulated to suit the velocity required for the fans."

Apparatus has also been supplied by this house to the Madison Square and Lester Wallack's Theatres and The Casino, New York City; the Boston Museum, and many other American halls and theatres.

diately under the auditorium floor the air is admitted through many 4 x 4 inch openings made through the brick arches into the space between the arches and the floor. From this space, the air for the occupants of the parquet chairs passes through the risers of the floor steps on which the chairs are set. In these risers are arranged openings continuous at their face, but of peculiar construction, and covered with No. 16 galvanized-iron perforated with 1-10 inch holes, a detailed drawing of which is given in Fig. 42.

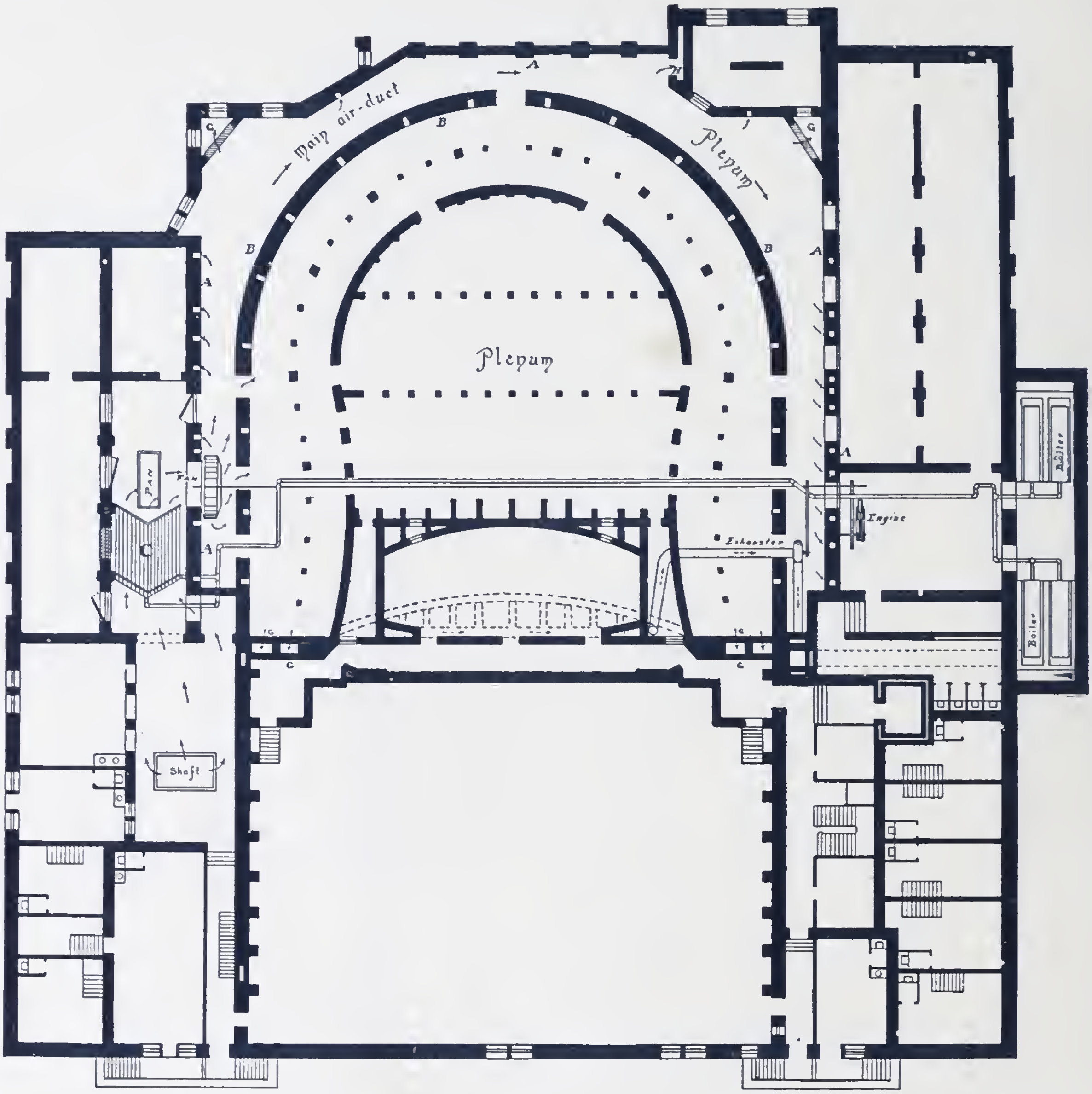


Fig. 39. Metropolitan Opera House, New York City. Ground Plan.

The air which supplies the boxes is carried from the main air duct in the flues in the wall *A* to the spaces between the floors and ceilings as shown on transverse section, and discharged at the edges of the tiers at *a a*. Its course is then upward and backward, to the flues in the wall *B*, which have an exhausting power derived from the heat of the gas jets under the hoods in the balcony and family circle, and from the gas light, when used, in the private parlor, immediately behind the chairs, a detail of which is shown in Fig. 43. The balcony and family circle receive air through the large flues *G G*, at the ends of the main air ducts in the proscenium wall and through the flues *G G* and *H* in the wall *A*. The air is discharged into the spaces shown, formed by the ceilings of the box parlors on the second tier and by the ceiling in the angle of the balcony at the walls. It is then distributed to the edge of the balcony and family circle at *a a* and through a 2 x 4 inch hole at the back of every chair in the risers of the galleries. By this means, every stationary chair in the house has air admitted to it.

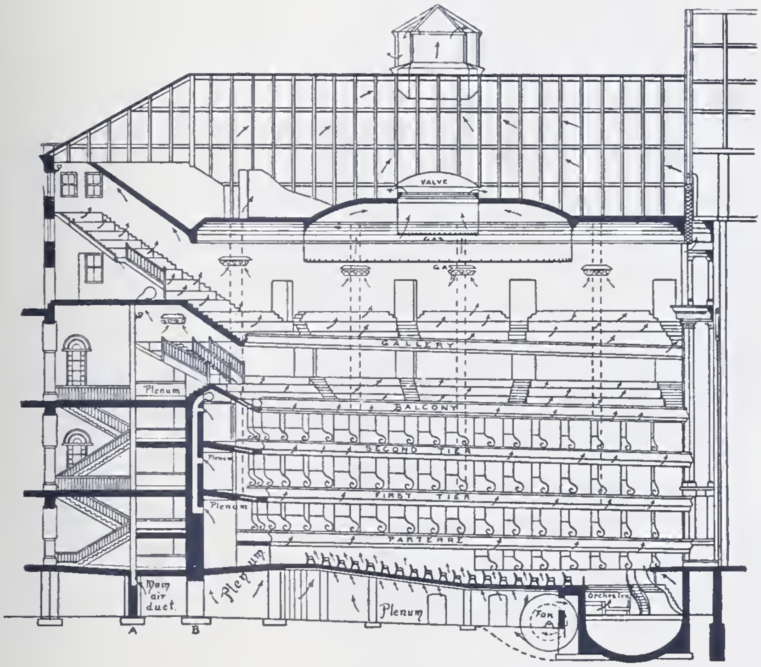


Fig. 40. Longitudinal Section.

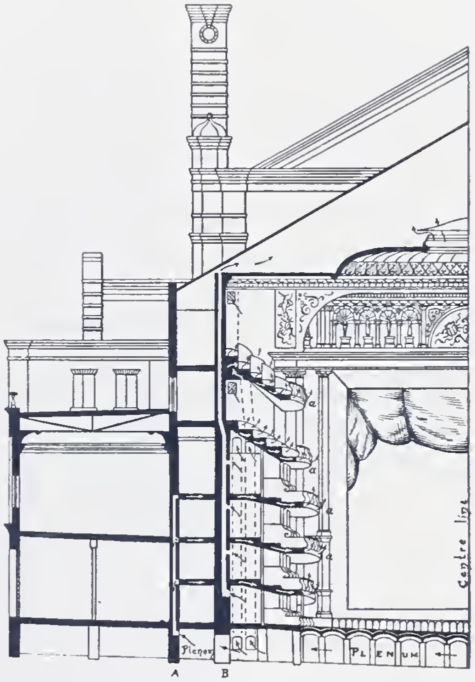


Fig. 41. Transverse Section.

Metropolitan Opera House, New York City.

" The outlets for foul air are those already mentioned in the boxes and which are shown in the wall *B* (ground plan), and those in the proscenium wall at the ends of the gallery and balcony. Such of the flues in the wall *B* as were cut off by the extension of the balcony and family circle toward Broadway) an after consideration) are carried in a galvanized-iron pipe, within the air space under the department of our manufacture and both fans and engines have been carefully designed to meet the requirements of such work. In Fig. 44, is represented the general style of fan and double engine, that is at the present time being put into vessels of this description. The engine is very strongly built, and being double cylindered with cranks opposite, perfect balance of reciprocating parts is secured, allowing the fan to be run at the high speeds necessary to produce the high pressure often required.

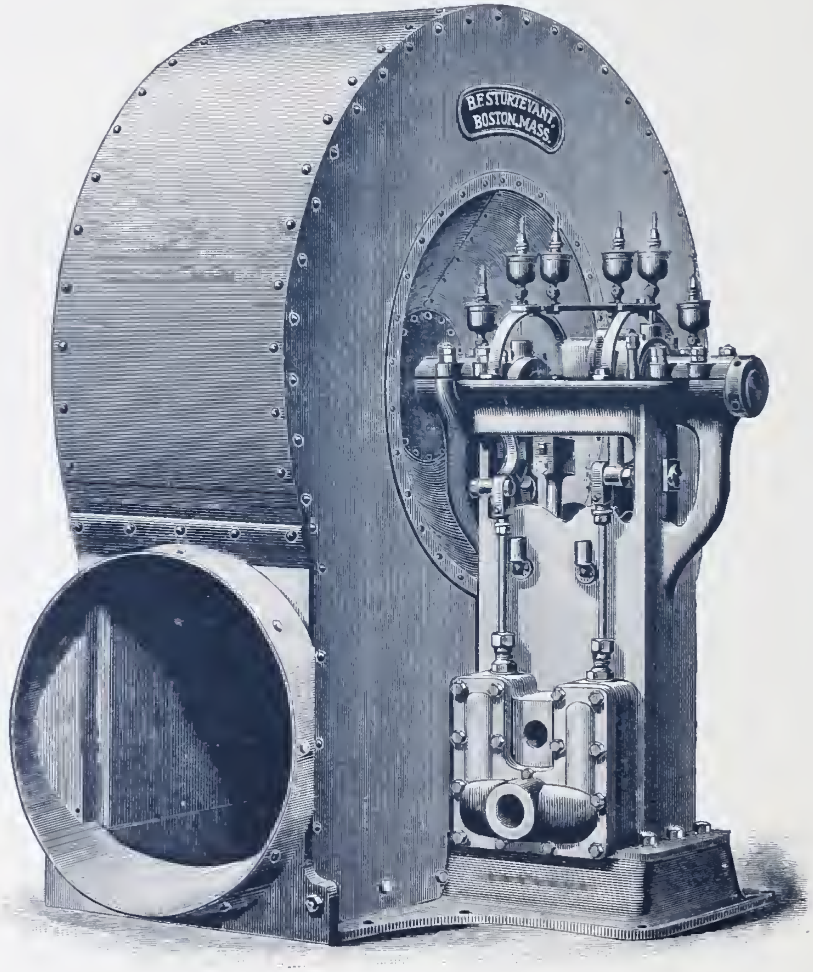


Fig. 44. "Navy" Steam Fan.

In place of ventilation by exhausting, as employed for certain parts of the vessel, fresh air is usually supplied under moderate pressure to the fire-rooms. A triple work is thus accomplished, for, not only is sufficient air furnished for ventilation, but this same air also answers as a cooling medium to the occupants and finding its exit through the fires to the smoke-stack, the rate of combustion is greatly increased.

Sturtevant's Fans are now being rapidly applied to vessels other than those of the U. S. Navy, and the experience gained in this line of work by this house enables it to carry out successfully, the complete ventilation of all vessels. Steam fans of this make, used in some cases in connection with a heating apparatus, are now employed on board many steam vessels, prominent among which are those of the Fall River Line, White Star Line, a number of large pleasure steam yachts, and individual vessels here and abroad.

Mines. Mines are particularly devoid of any natural means of ventilation and only mechanical devices can supply them with fresh air. The air may be either exhausted from or forced into a mine. In either case ducts are necessary for the passage of the fresh or the foul air. Under the exhaust system, pipes and flues are extended to such parts of the mine as need to have the foul air removed and a circulation is created by an exhaust fan placed at the surface and connecting with these passages. Fresh air is supplied through the natural passages and shaft of the mine. When the air is forced in, the outlet of the blower is attached to the pipe system and fresh air delivered at the various points while the foul air escapes through the passages and shafts. The Sturtevant Fan is applicable to either method, and has been extensively introduced in the mining regions.

Drying. The Sturtevant Steam Hot Blast Apparatus has been very extensively applied for drying all materials, such as lumber, brick, wool, cotton, tobacco, grain, glue, etc. Thousands of such apparatus have been put in and always with increased economy and satisfactory results. The perfect circulation of the heated air and the perfect control under which it is held, not only as to temperature and velocity, but above all, as to humidity, render it capable of meeting all requirements. Certain materials require varying temperatures and humidities of the air during the process of drying, which can only be met by this apparatus.

The lumber drying business has increased to such an extent, that we have gotten out complete building plans for lumber dry-houses, of various capacities and construction, and these are supplied to all purchasers of the apparatus designed for this line of work.

A separate "Special Sectional Illustrated Catalogue of B. F. Sturtevant's Steam Hot Blast Drying and Heating Apparatus, as applied to Drying Lumber, etc.," will be mailed to any parties desiring further information in the matter of drying.

Testing Systems of Ventilation and Heating.

The actual efficiency of any system of ventilation and heating cannot be ascertained by a mere casual inspection, but only by careful, intelligent and extensive experiment. Trustworthy results can only be obtained by the use of special instruments designed for such investigations. Among the most important are those here presented.

Good thermometers, of the usual construction, are generally sufficiently accurate for observing the ordinary temperature of air, but for noting the temperature of steam, or of highly-heated air, the form shown in Fig. 45 (as constructed by Huddleston, of Boston) is very convenient. The thermometer tube is enclosed in a tubular brass case, the lower end of which is provided with a screw of standard size and thread, by means of which it may be securely inserted in any T or flange. The tube projects well down below the threaded portion and is guarded by a small pipe attached to the bottom of the case, which allows free circulation around the bulb of the thermometer.

The graduations can be made to read to any requirement and may take a range between any given temperatures.

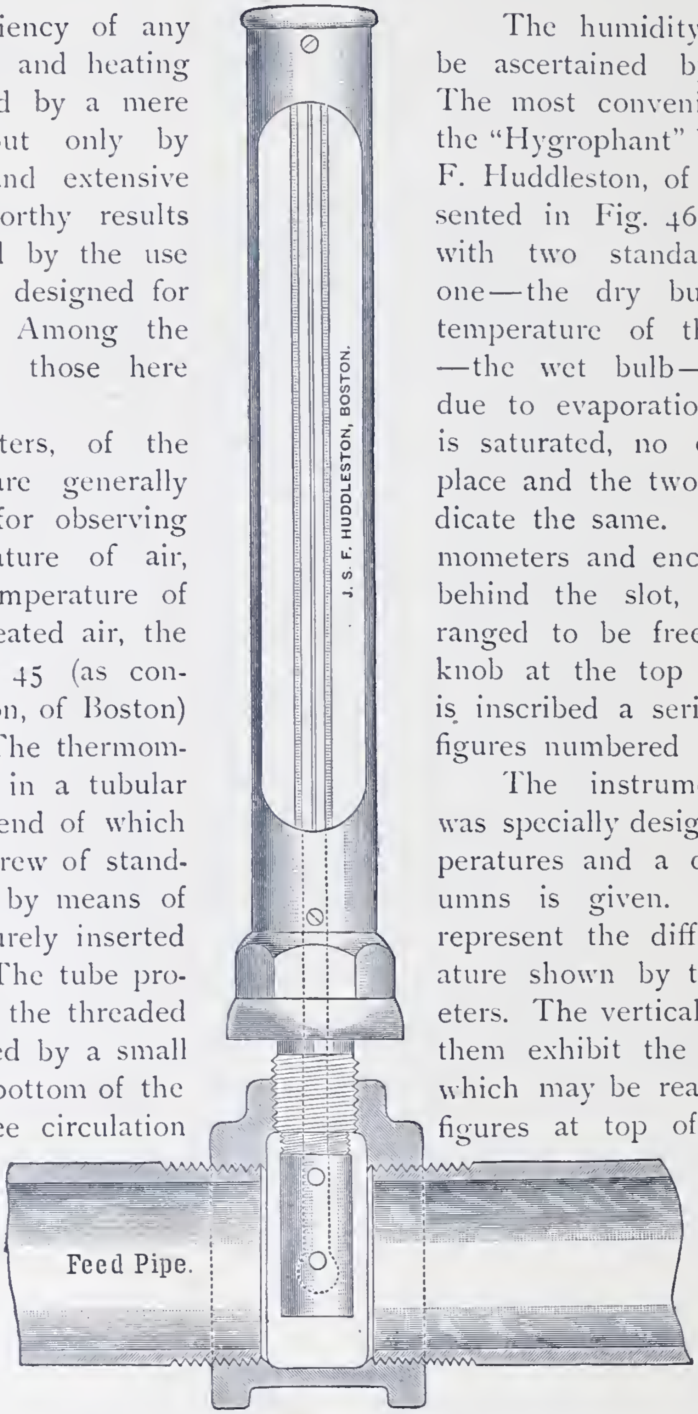


Fig. 45. High Grade Thermometer.

The humidity of the air may be ascertained by a hygrometer. The most convenient form, termed the "Hygrophant" by its maker (J. S. F. Huddleston, of Boston,) is represented in Fig. 46. It is provided with two standard thermometers, one—the dry bulb—showing the temperature of the air, the other—the wet bulb—the temperature due to evaporation. When the air is saturated, no evaporation takes place and the two thermometers indicate the same. Between the thermometers and enclosed in the case, behind the slot, is a cylinder, arranged to be freely turned by the knob at the top and upon which is inscribed a series of columns of figures numbered at their headings.

The instrument here shown was specially designed for high temperatures and a double set of columns is given. These numbers represent the difference in temperature shown by the two thermometers. The vertical columns beneath them exhibit the relative humidity, which may be read off beneath the figures at top of column, indicating the difference of temperatures and opposite to the temperature of the wet bulb, as shown on the scale at the left of the cylinder.

The volume of air flowing through a given passage can be ascertained by finding the velocity of flow, by means of an anemometer, and multiplying this by

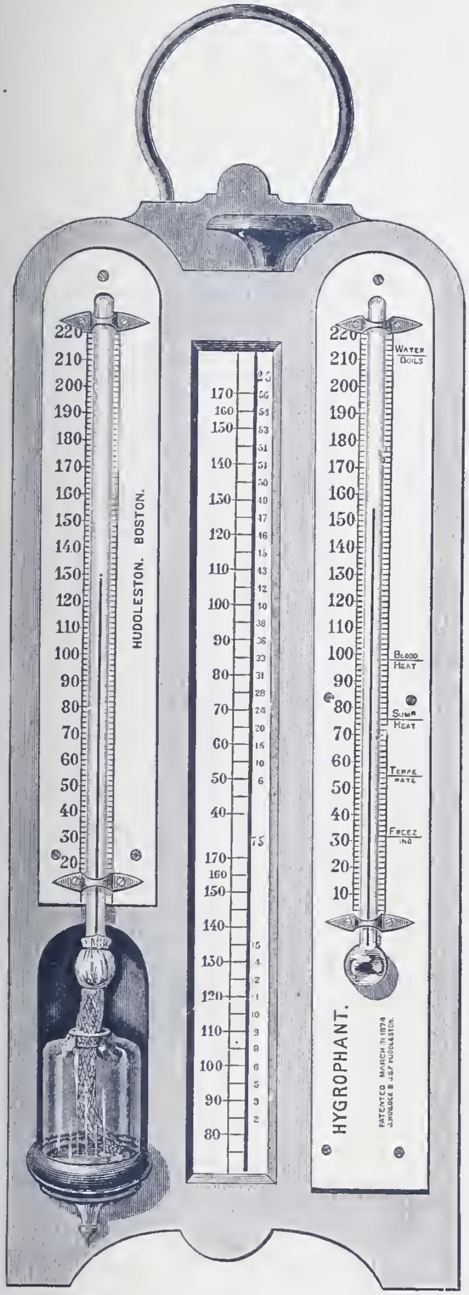


Fig. 46. Hygrophant.

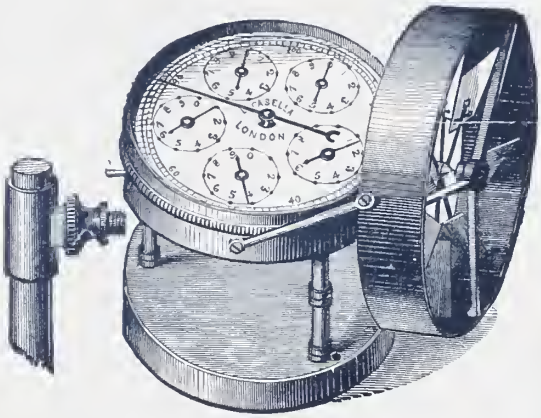


Fig. 47. Anemometer.

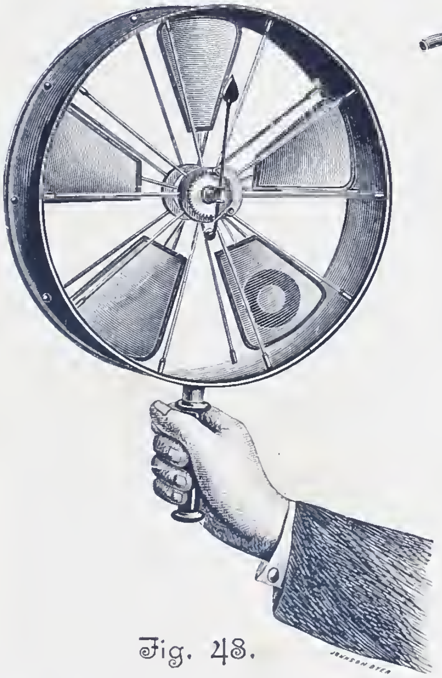


Fig. 48.
B. F. Sturtevant's Anemometer for Testing Slow Currents.

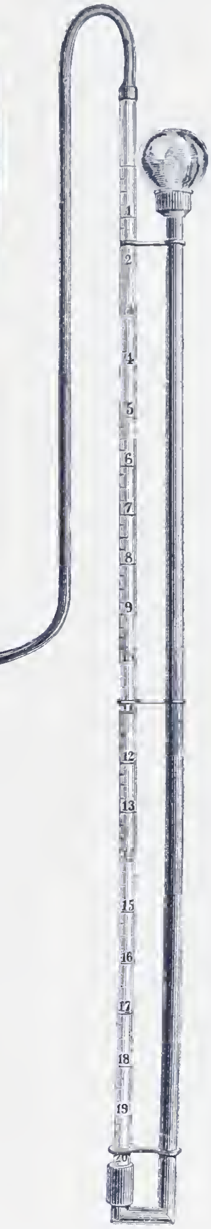


Fig. 49.
B. F. Sturtevant's Air Pressure Gauge.

the area of the cross section of the passage. Fig. 47 represents the most approved form of the instrument. The number of feet traversed by the air is shown upon a series of dials, indicating 100, 1,000, 10,000, 100,000, 1,000,000 and 10,000,000 feet respectively. By noting, by means of a time piece, the number of feet traversed in any given time by the air, the velocity per unit of time may be obtained.

A much simpler form, although decidedly larger, is that shown in Fig. 48, as made by B. F. Sturtevant, for indicating very slow currents. It is very light and carefully balanced and will render apparent currents which are otherwise imperceptible.

The pressure of air or the vacuum in any enclosed space is readily indicated by the air pressure gauge in the form constructed for the trade by B. F. Sturtevant, and shown in Fig. 49. The rubber tube is connected with the space and the pressure or lack of pressure in this space, causes the water in the tube to fall or rise, according to which condition exists. The bulb is filled with water and being of considerable size, a change of level in the tube has practically no effect upon the level in the bulb, and consequently a constant head is maintained. The tube is graduated to quarter inches, which may be readily reduced to ounces, when it is known that a column of water 27.672 inches in height will give a pressure of one pound to the square inch.

The relative amount of carbonic acid present in the atmosphere may be readily ascertained to a sufficiently close degree, for practical purposes, in the following manner. Six clean, dry and well stoppered bottles, containing respectively 100, 200, 250, 300, 350 and 400 cubic centimeters, a glass tube containing exactly 15 cubic centimeters to a given mark, and a bottle of perfectly clear, fresh lime-water constitute the apparatus required. The bottles should be filled by means of a hand-ball syringe with the atmosphere to be examined. Add to the smallest bottle 15 cubic centimeters of the lime water, put in the cork and shake well. If turbidity appears, the amount of carbonic acid will be at least 16 parts in 10,000. If no turbidity appears, treat the bottle of 200 cubic centimeters in the same manner; turbidity in this would indicate 12 parts in 10,000. In similar manner, turbidity in the 300 cubic centimeter bottle indicates at least 10 parts in 10,000; in the 300, 8 parts; in the 350, 7 parts; and in the 400, less than 6 parts. The ability to conduct more accurate analyses can only be attained by special study and a knowledge of chemical properties and methods of investigation.